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Final Data and Analysis Report on: High-Resolution in Plume Concentration Fluctuations Measurements using Lidar Remote Sensing Technique

Torben Mikkelsen, Hans E. Jørgensen, Søren Thykier-Nielsen,
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Abstract The multi-nation, high-resolution field study of Meteorology and Diffusion over Non-uniform Areas (MADONA) was conducted by scientists from the United States, United Kingdom, Germany, Denmark, Sweden, and The Netherlands at Porton Down, Salisbury, Wiltshire, UK during September and October 1992. The host of the field study was the Chemical and Biological Defence Establishment at Porton Down. MADONA was designed and conducted for high resolution meteorological data collection and diffusion experiments using smoke, sulphurhexaflouride (SF_6), and propylene gas during unstable, neutral, and stable atmospheric conditions in an effort to obtain terrain-influenced meteorological fields, dispersion, and concentration fluctuation measurements using specialized sensors and tracer generators. Thirty-one days of meteorological data were collected during the period 7 September through 7 October and 27 diffusion experiments were conducted from 14 to 23 September 1992. Puffs and plumes of smoke and SF_6 were released simultaneously for most of the experiments to gauge the resultant diffusion and concentration behavior. Simultations of airflow and diffusion over the MADONA topography were made with a variety of models. Wind fields and wind-related parameters were simulated with several high resolution wind flow models. A tally of the various data gathering activities indicates that the execution of MADONA was highly successful. Preliminary use of the data sets is showing the high quality and dept of the MADONA data base. This well-documented data base is suitable for the evaluation and validation of short range/near field wind and diffusion models/codes. The data base has been placed on CD-ROM media in a structured way by CBDE, Porton Down.

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7-25 SEP. 1992.

Final Data and Analysis Report on:

HIGH-RESOLUTION IN-PLUME CONCENTRATION FLUCTUATIONS

MEASUREMENTS USING LIDAR REMOTE SENSING TECHNIQUE

by

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1 Introduction

1.1 Summary

The multi-nation, high-resolution field study of Meteorology And Diffusion Over Non-uniform Areas (MADONA) was conducted by scientists from the United States, United Kingdom, Germany, Denmark, Sweden, and The Netherlands at Porton Down, Salisbury, Wiltshire, UK during September and October 1992. The host of the field study was the Chemical and Biological Defence Establishment at Porton Down. MADONA was designed and conducted for high resolution meteorological data collection and diffusion experiments using smoke, sulphurhexafluoride (SF_6), and propylene gas during unstable, neutral, and stable atmospheric conditions in an effort to obtain terrain-influenced meteorological fields, dispersion, and concentration fluctuation measurements using specialized sensors and tracer generators. Thirty-one days of meteorological data were collected during the period 7 September through 7 October and 27 diffusion experiments were conducted from 14 to 23 September 1992. Puffs and plumes of smoke and SF_6 were released simultaneously for most of the experiments to gauge the resultant diffusion and concentration behavior. Simulations of airflow and diffusion over the MADONA topography were made with a variety of models. Wind fields and wind-related parameters were simulated with several high resolution wind flow models. A tally of the various data gathering activities indicates that the execution of MADONA was highly successful. Preliminary use of the data sets is showing the high quality and depth of the MADONA data base. This well-documented data base is suitable for the evaluation and validation of short range/near field wind and diffusion models/codes. The data base has been placed on CD-ROM media in a structured way by CBDE, Porton Down.

1. US Army Research Laboratory, White Sands Missile Range, NM, USA;
2. German Military Geophysical Office, Mont Royal, D-56841 Traben-Trarbach, Germany;
3. US Army Dugway Proving Ground, Dugway, Utah;
4. Chemical and Biological Defence Establishment, Porton Down, Salisbury, Wiltshire, United Kingdom;
5. TNO Prins Maurits Laboratory, Rijswijk, The Netherlands;
6. National Defence Research Establishment, Department of NBC Defence, S-901 82 Umeaa, Sweden;
7. Department of Meteorology and Wind Energy, Risø National Laboratory, P.O. Box 49, DK-4000 Roskilde, Denmark;
8. Meteorological Office, Larkhill, Wiltshire, United Kingdom;
9. German Aerospace Research Establishment, Oberpfaffenhofen, Germany.

The Department of Meteorology and Wind Energy at the Risø National Laboratory in Denmark participated and supported:

MADONA:

Meteorological And Diffusion Over Non-uniform Area

Full-Scale Diffusion Trials Conducted at

Porton Down, Salisbury

CBDE-UK; Sep. 7 - 25 1992.

The Risø Mational Laboratory, Department of Meteorology and Wind Energy, contributed with the following activities:

1) Continuous smoke dissemination from ground level sources.
2) High-resolution profile-measurements of instantaneous plume dispersion and concentration fluctuations by use of a mini-LIDAR system. (Remote sensing)
3) Micro-meteorological measurements of wind and temperature quantities from two 7 meter tall met-towers equipped with 20 Hz sonic anemometers for characterization of the mean and turbulent state of the boundary layer.
4) Mean wind and diffusion modelling using our real-time diagnostic models LINCOM/RIMPUFF.

1.2 Objectives

The scientific objective for our participation in MADONA was to investigate fundamental questions regarding the statistical properties of the instantaneous concentration fluctuations in smoke plumes and puffs. The joint-venture Porton Down experiments, with international participation and support facilitated this objective. Modelling objectives included investigation and experimental evaluation of flow and diffusion modelling based on our LINCOM/RIMPUFF real-time codes.

With our high-resolution mini-lidar system, sequential measurements (1/3 Hz) were obtained of the instantaneous cross wind concentration profiles at fixed down wind distances from the source. The source consisted of ground level continuous smoke releases and elevated smoke puff releases.

The cross wind concentration profiles were measured with an effective spatial resolution of 1.5 meter.

From the conducted puff and plume diffusion experiments, we have by post-processing and data reduction obtained important concentration fluctuation statistics including:

Mean- and variance profiles, intermittency profiles, probability distribution functions, dispersion parameters (including instantaneous puff width). In addition we distinguish statistics obtained in a fixed frame (absolute diffusion), and center-of-mass frame (relative diffusion).

Derived statistics include:

Dispersion coefficients, and their dependence on sampling time (from instantaneous to length of experiments, typically 1-hour.)

Two-particle distance-neighbor functions yielding information about the instantaneous spatial correlation function of in-plume fluctuations.

Extreme statistics of excedance of certain reference levels, and the (ensemble mean) duration of such excedances.

Our Lidar based concentration fluctuation measurements were supported by our micro-meteorological observations from two tower mounted sonic anemometers, in addition to the joint mean wind and turbulence data gathered simultaneously by the participating groups at Porton Down.

1.3 Background

Within the CEC Radiation Protection Research Programme for Nuclear Safety, Risø is commissioned to conduct reference smoke plume dispersion experiments, where we based on the mini-LIDAR facility are studying concentartion fluctuations for dispersion model evaluation and model uncertainty assessments. Also, we are conducting full scale reference and training experimental data for the CEC supported real-time decision support system RODOS, where atmospheric dispersion is a key element.

The layout and experimental set-up for the Porton Down MADONA experiments, including the many other participants, provided an unique opportunity to combine and jointly perform already scheduled uncertainty and evaluation experiments with the general objectives for MADONA.

Our entire scientific outcome from the smoke diffusion trial are consequently offered for inclusion in the MADONA data base, including the basic scientific analysis as described above.

All raw and statistical analyzed data from our LIDAR and micro meteorological measurements are shared. The latter includes 10-min mean and turbulent scaling parameters such as variances, energies, shear stress and heat flux (Monin-Obukhov length).

1.4 Reporting and Availability of Results

This data report describes the experimental setups, time periods and atmospheric conditions for the MADONA trials.

Our final results are given in the included 4 papers to be presented at the 11th AMS Boundary Layer and Turbulence symposium in Charlotte, NC, USA during the period 27-31 March 1995.

1.5 Acknowledgements

Risø obtained additional financial support for expenses associated with moving our experimental facilities and personnel to Porton Down,UK.

Our participation in the MADONA trials were hereafter made possible by support from the CEC Radiation Protection Research Programme, DGXII, under contract No. BI7-0017-C, and by a grant from the US Army Research Branch, London, under contract No. DAJA45-92-M-0344. Mr. Ron Cionco at the U.S. Army Atmospheric Science Laboratory, White Sands, MN., USA and Mr. Jerry Comati at the US Army Research Branch, London, are gracefully acknowledged.

2 Technical Description

2.1 Mean and Turbulence Measurements from two Micro-Meteorological Masts

Two 7 meter high meteorology mast were erected and instrumented at the Porton Down site near the Westerly source point, see Fig. II.1. (Porton Down landscape seen from South-West.)

The met-towers were each equipped with Kaijo Denki DAT 300 sonic anemometers in order to obtain both mean-profile and turbulence scaling parameters for the MADONA dispersion trials.

Appendix II.1: **Contains directly measured mean and turbulence quantities, including:1) Mean Wind speed,2) Direction,3) Turbulent Kinetic Energy, 4) Stress, 5) Sensible Heatflux, 6) Monin-Obukhov Stability parameters and 7) Temperature statistics.**

Appendix II.2 **Comparison between 5 and 10 min averaged statistics for day: 23/9 192; sonic 1 and sonic 2.**

The measurements were obtained from two acoustic three-dimensional sonic-anemometer/thermometers (Kaijo Denki type DAT-300), located at 7 meter level above the floor.

Running continuously during the entire experimental campaign, they provided us with real-time, on-line surface layer turbulence statistics of the most important scaling parameters for dispersion. By use of our PC-based on-line data acquisition system and associated computers, we measured and calculated (in real-time) the entire co-variance matrix of the fluctuating quantities u',v',w' and T' (by the correlation-method), and from here, the velocity and temperature intensities, the shear-stress and the sensible heat flux was deduced at 10-min intervals in real time. With the additional information of the inversion height from rawin-sonde balloons (not provided by Risø), the sonic anemometer data enables us to calculate the very important scaling parameter for convective conditions: W_*.

Our sonic-based on-line "turbulence monitoring-system" provides the experimenters and the project-manager with real-time measurements of the atmospheric stability and turbulence state at Porton Down, concurrently with each diffusion test and provided also direct measurements of the variances and fluxes requested for the subsequent model evaluation study.

The Risø Sonic-DAS-system was put in continuous operation throughout the whole experimental period.Our directly measured, 10-min averaged quantities included:<u'u'>, <u'v'>, <u'w'>, <u'T'>, <v'v'>, <v'w'>, <v'T'>, <w'w'>,<w'T'>, <T'T'>, in addition to the mean wind speed and mean temperature.

The accuracy of the sonic anemometer/thermometer type DAT 300 is, according to the manufacturer (Kaijo Denki Co.): +/- 1% on measured velocity and temperature signals, the resolution is 0.5 cm/s and 0.025 K, respectively. It measures all signals 20 times per second and has a 10 Hz low-pass output filter. For measurements taken 7 meter above the ground, this instrument will provide very adequate resolution of the turbulent signals, both with respect to spatial and temporal resolution: The on-line data acquisition system (DAC_SYS) point-samples the four signals U,V,W and T at a rate of 10 Hz, and subsequently calculates the co-variance matrix after each 10-min period based on the corresponding 6000 readings of each signal.

The directly measured time series (consisting of four times 6000 measurements each per 10-min period) are also stored for subsequent spectral analysis.

Data-, both mean and of the turbulence quantities, have already been processed, stored and backed-up as 10-min average quantities. Additional to visual inspection of raw time series, more objective quality assurance in accordance with Højstrup, 1993 will be performed on central data periods.

2.2 High-Resolution Time-Series and Spectral Analysis

Additional spectral analysis can at request be performed on 10-min average meteorological quantities. For each of the scheduled diffusion tests, the following is available on request:

1. Time series plots of high-resolution (10 Hz) wind and temperature signals from the sonic anemometer.
2. Time series of short-time averaged (1-min running mean) quantities of wind speed, direction, turbulence level, shear stress and heat flux.
3. Spectral analysis of the three wind (u',v',w') and temperature (T') signals.

This information is of importance in a subsequent modelling evaluation. in particular for:

I Gaining insight into the fine scale temporal evaluation of the boundary flow and turbulence in the valley during each diffusion test.

II gaining insight into which turbulent scales are of importance and most energetic, and consequently responsible for the exchange and diffusion processes, and

III Providing detailed turbulence measurements at the source point for use in the subsequently planned model simulation of the experiments.

We provide on request, for each of the successfully performed diffusion tests:

re i. 10-Hz digitized raw data of U,V,W and T on PC-diskette.

re ii. Time series plots of sonic data and of the correspondding 1-min running mean turbulence quantities.

re iii. Plots of the three velocity spectra and the temperature spectrum from 0.001 to 5 Hz.

3 LIDAR-Measurements of Surface-Released Smoke Plumes

The Risø National Laboratory operates a mini-LIDAR system for determination of instantaneous concentration profiles inside dispersing aerosol-plumes.

The system yields high spatial and temporal resolution measurements of in-plume concentration fluctuations, from which important and basic scientific plume dispersion characteristics can be inferred.

For the MADONA trials, we provided a powerful and sturdy artificial smoke generator, which produced ground-level releases of smoke plumes or elongated puffs.

The smoke consisted of non-toxic white plume of sub-micron aerosols. The aerosols were conglomerated SiO_2 and NH_4OH that is detectable by our 1.064 μ lidar system. In this way, measurements of the cross-wind near-ground concentration profiles were obtained at various distances downwind.

During evenings and nights with stable atmospheric conditions, the lidar system can pick up the smoke plume concentrations out to several kilometers from the source point.

At Porton Down, the mini-LIDAR system measured instantaneous "snapshots" every 3. or 5. second of the aerosol back-scatter cross-section.

Appendix III.1: **Contains information of lidar positions and measurement periods obtained at the MADONA trials. It includes also drawings of source and lidar positions for the total of 23 experiments. See also RUN_DOC Appendix IV.**

Appendix III.1: **LIDAR scanned mean concentrations from MADONA experiment No. 22f (1 hour 22 min continuous release).**

Appendix III.2a-d: **From Madona exp. No. 15h: Lidar measured mean, variance, fluctuation intensity and intermittency crosswind profiles in fixed frame (meander included).**

Appendix III.3a-d: **From Madona exp. No. 15h: Lidar measured mean, variance, fluctuation intensity and intermittency crosswind profiles in moving frame (meander removed).**

The measurements related to the number of aerosols in the small measurement volume, which is a "cigar-shaped" cylinder of approx. 1 meter in diameter and approx. 1.5 meter long.

Extensive data-processing of the raw lidar-signals is in progress in order to produce accurate and quality-assured cross-wind aerosol concentration profiles. In return, we obtain from each experiment, not only the mean concentration profile, but also a measure of the natural fluctuation and inherent uncertainty associated with dispersion. This is of importance for subsequent model evaluation studies.

During madona, we obtained both stable, neutral and unstable experiments based on both plume and puff releases. The release rate of the aerosol generator was kept constant during individual experiments.

Our contribution to the MADONA data base contains, for each experiment:

1) Time series of cross-wind profiles
2) Plots of mean cross-wind concentration
3) Plots of fluctuating (rms)
4) Plots of in-plume intermittency
5) Measurements of the entire measured concentration pdf (probability density distribution) from which, for instance, different exceedance statistics and high-level exposure events can be inferred.

The posterior data processing, reduction and analysis of our Lidar-activity is rather involved, and will require between 6 and 12 month of data preparation and analysis following the experiments to finalize.

4 Modelling

4.1 Mean-Flow Modelling: Real-Time Diffusion Model Simulations

The local-scale real-time dispersion modelling system LINCOM/RIMPUFF is evaluated using data from the complex terrain Guardo experiments carried out in Northern Spain November 1990.

Releases of tracer gas (SF_6) were simulated from a 185 m tall buoyant power plant stack, and from a valley floor release (10 m). The observed wind flow and plume diffusion is modelled and compared with tracer gas measurements. Studies reported in this paper include one daytime up-valley breeze situation and one nighttime down-valley drainage flow situation.

Wind and turbulence data were obtained from a network of 9 meteorological towers over the 40x40 Km experimental domain, accompanied by balloon and acoustic soundings.

The study shows that a linearized dynamic flow models, when properly initialized (assimilated) by observations, is an attractive alternative to the diagnostic mass consistent models for real-time applications.

Simulations of the airflow and diffusion over the MADONA topography were made with a variety of models. Several simulations were made on-site and in real-time, while others were made after the experiment during the analyses of the observed wind and diffusion pattern. Wind fields and wind-related parameters were simulated with high resolution wind models such as HRW, Ball and Johnson and LINCOM.

LINCOM is a non-hydrostatic diagnostic model based on the solution of linearized continuity and momentum equations with a first order spectral turbulent diffusion closure. It processes a single layer of 100x100 grid points in less than 10

seconds on a 486 IBM compatible PC. Its truncated physics of course restricts its application over severe non-uniform terrain, but considerable realism in the flow fields was achieved by use of assimilation techniques to match results to measured tower or forecast winds.

The puff diffusion code RIMPUFF is designed for real-time episode modeling of hazardous cloud dispersion during time and space changing meteorology. The model is provided with a puff splitting feature to handle plume bifurcation and shear flow over non-uniform terrain. The puff growth process is controlled by local turbulence levels, derived from on-site measurements.

Diffusion of smoke and tracer gas was calculated by RIMPUFF using the wind fields calculated by LINCOM. Several MADONA experiments have been simulated with RIMPUFF and other diffusion models. Results are compared using various qualification factors: relative Chi square, correlation factor and mean error factor.

In connection with our on-going activities with the CEC-RODOS activities for real-time on-line decision support, we additionally setup our modelling system LINCOM/RIMPUFF at the MADONA site:

For mean-flow wind field calculations at the Porton Down experimental area, we have setup our fast PC-version of LINCOM to calculate winds over the experiment site at various heights and for different synoptic wind directions. LINCOM is a non-hydrostatic spectral, neutral wind code, cf. Santabarbara (1993).

LINCOM is setup to run based on the measured tower winds and as such, it is suitable as driver for dispersion studies over complex terrain. Alternatively, the model can run on a single wind speed and direction as input, if the dominating winds are driven by synoptic forces.

Our studies include comparison of measured tower winds with model results based on single inputs, the MADONA study with several wind observations are unique for this model/data intercomparison.

At present this flow model is under development in order to incorporate the effect of thermally driven forcing such as night-time drainage flows and day-time up-valley breezes. Since this model is a central as a "driver" for our puff-dispersion model RIMPUFF in complex terrain, it is worthwhile to test its applicability for the Porton Down terrain in question,- and possibly even use the obtained results from these experiments in order to evaluate our efforts regarding improving the model to include the effects of thermal forcing.

4.2 Combined Mean-Wind and Dispersion Models for Real-Time Plume Dispersion Assessment over Undulating Terrain

Our dispersion modelling work is centered about a Lagrangian Mesoscale Puff-diffusion model (RIMPUFF), which over the years has obtained acknowledgement and use internationally, for instance in the UFOMOD and the COSYME consequence assessment systems available in public domain by the CEC. For dispersion calculations over complex terrain, the PC-based RIMPUFF model is presently twinned with the non-hydrostatic mean flow model LINCOM, which is based on the Navier-Stokes equations for motion, including mass, momentum and heat conservation. The combination of the flow and diffusion model results in an extremely fast computer code, which advantageously can be tested and evaluated in real time with experimental data from the present diffusion experiments.

A modelling effort based on selected MADONA diffusion trials is consequently in progress.

Appendix IV:	**Contains the first preliminary model results of wind and diffusion calculations from the MADONA trials:** Sep 17, release time 11:10 - 16:10.
Fig. IV.1:	Shows LINCOM output of hourly consecutive wind field calculations based on tower data inputs.
Fig. IV.2:	Shows detailed stream line plot of one of these wind fields, including tower wind data???
Fig. IV.3:	Shows instantaneous plume positions at ten minute intervals and also total integrated concentration (dose).
Fig. IV.4:	Porton Down terrain vertical magnified x 20 seen from southwest
Fig. IV.5:	Example of tower data representation for Lincom inputs.
Fig. IV.6:	Example of Lincom grid wind field (10 meters height) 300 meter horizontal resolution
Fig. IV.7:	As Fig. IV.6, 100 m horizontal resolution.
Fig. IV.8:	Example of stream line wind field from neutral LINCOM (10 meters height) at Porton Down terrain.

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(Highlighted References are fully included at the end, Appendix IV)

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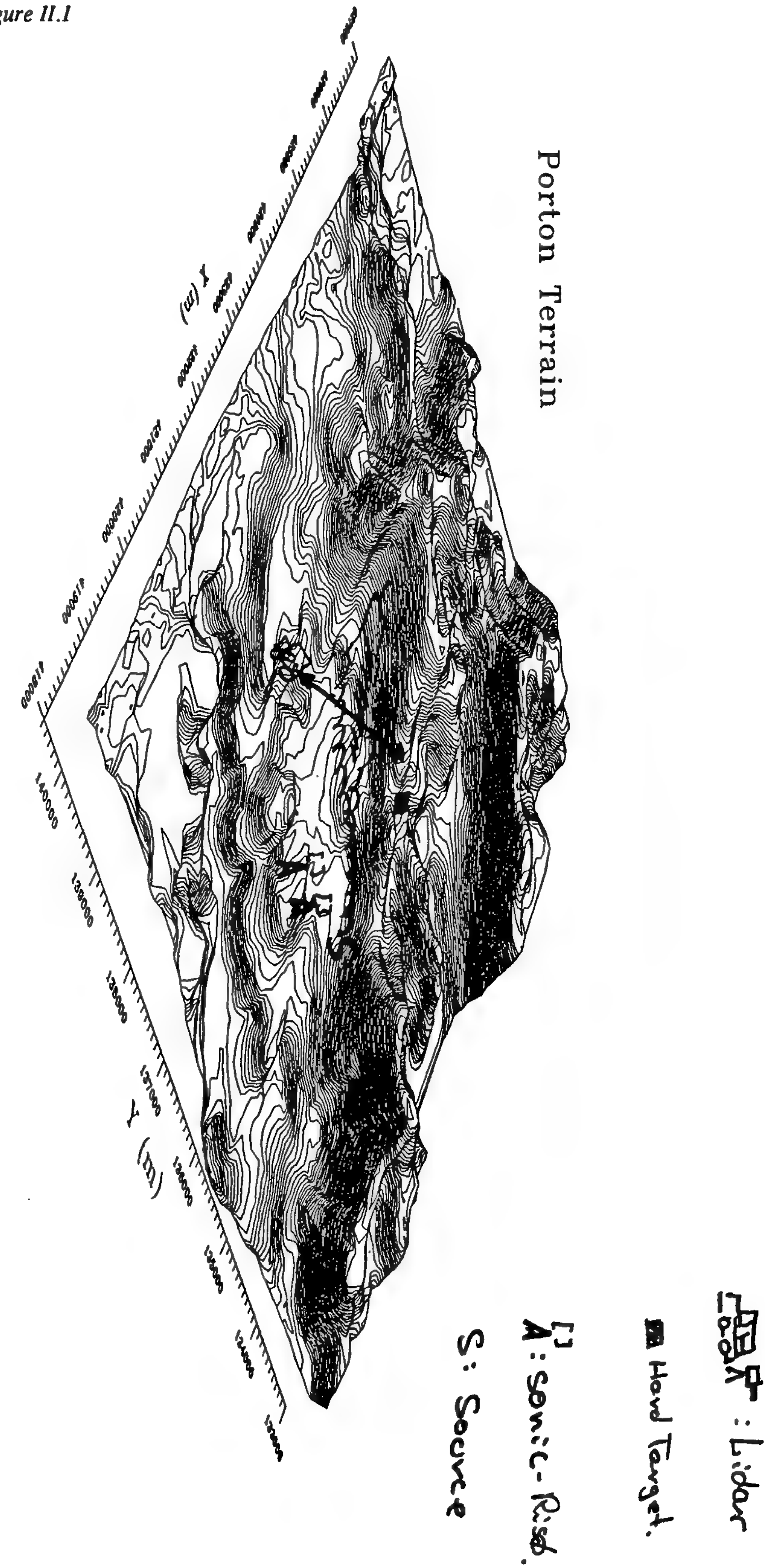
Figure II.1



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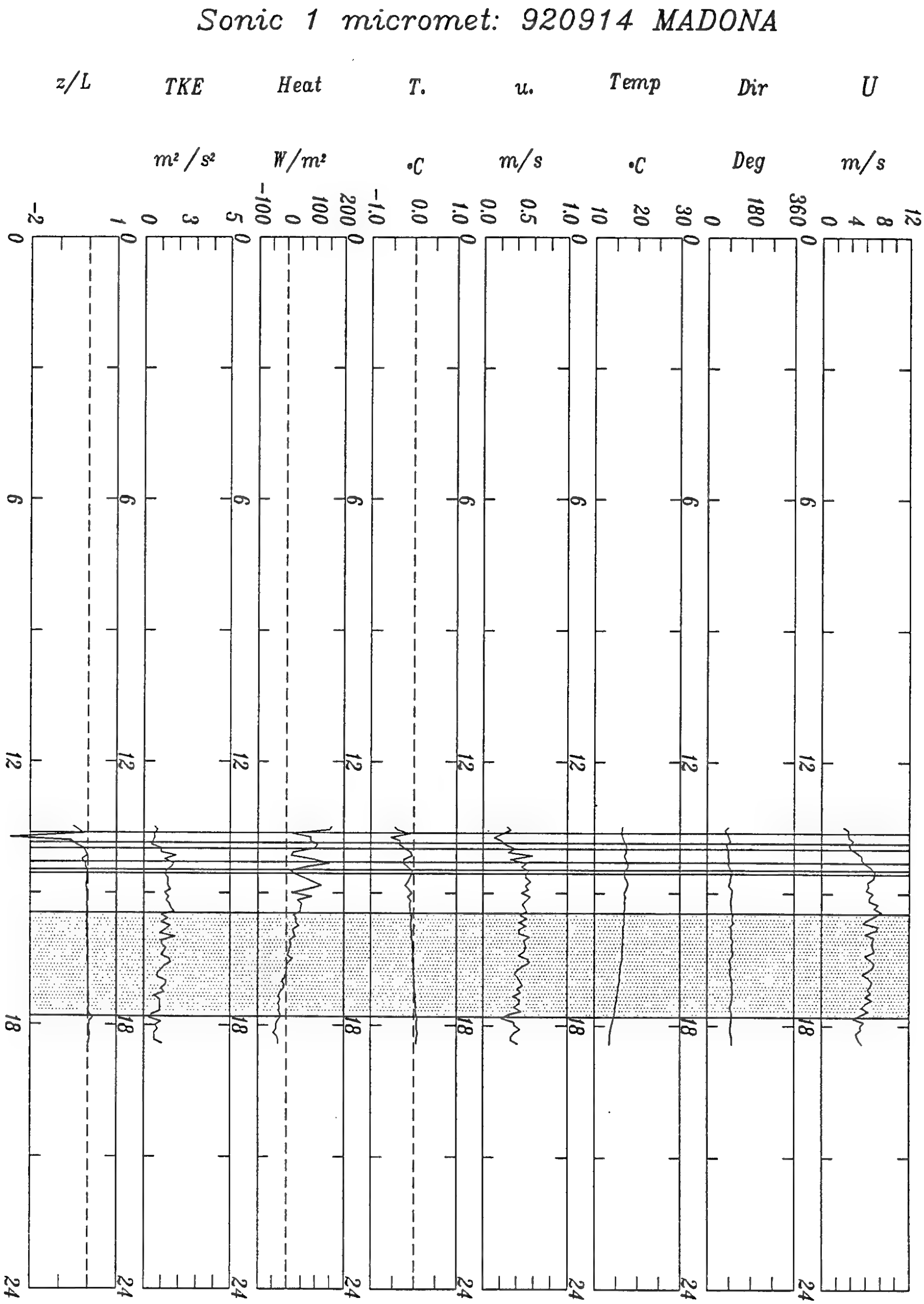
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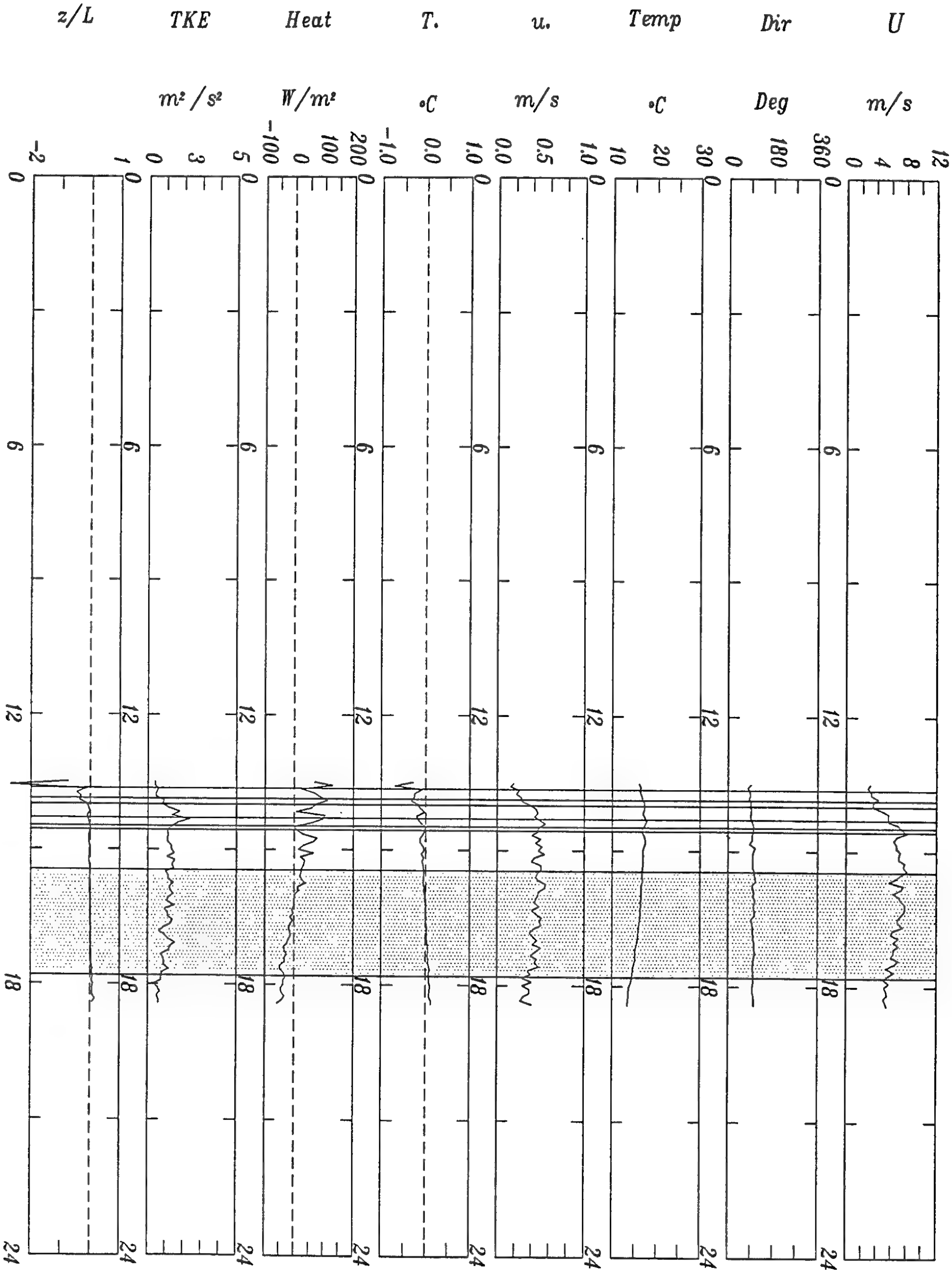

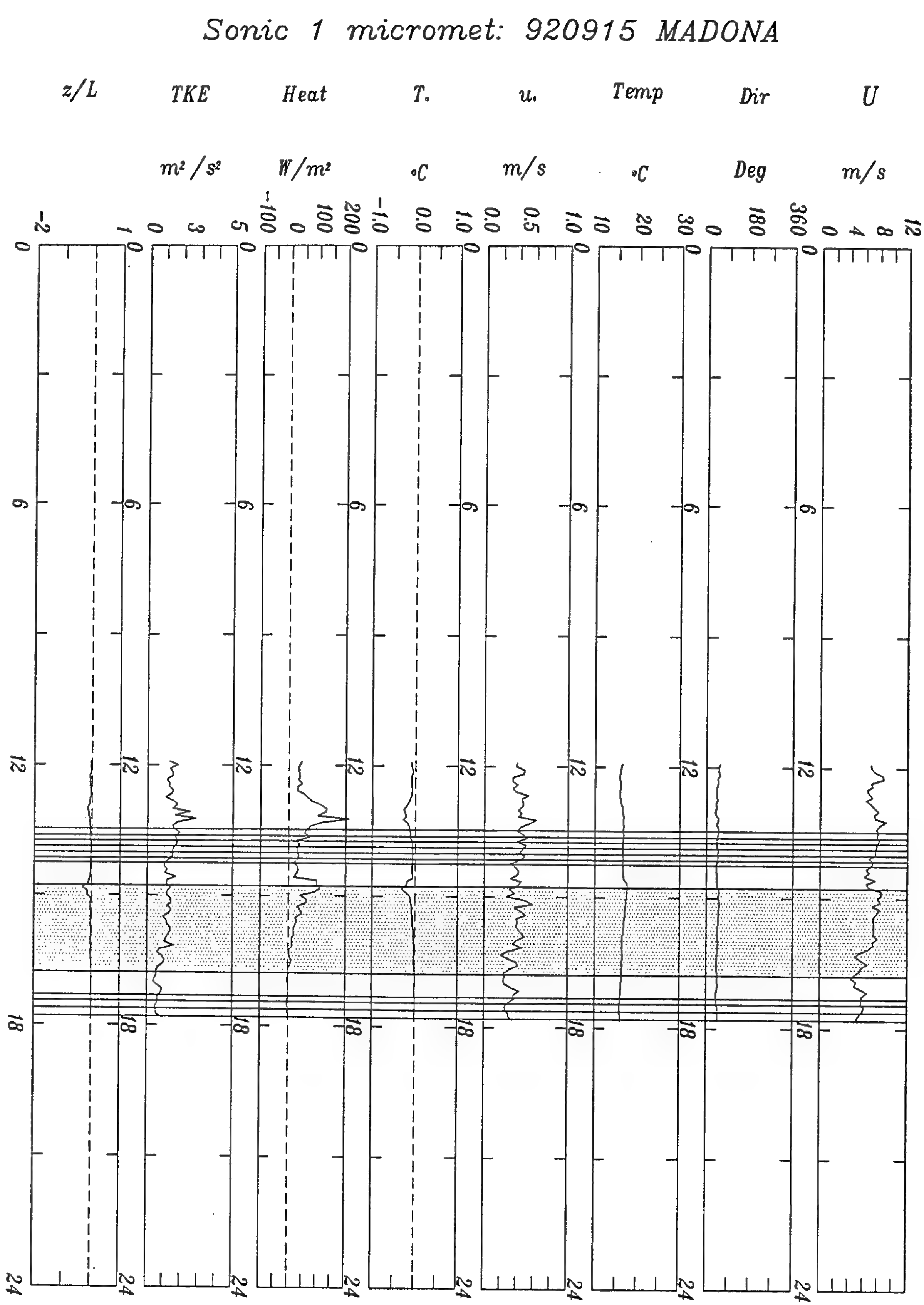

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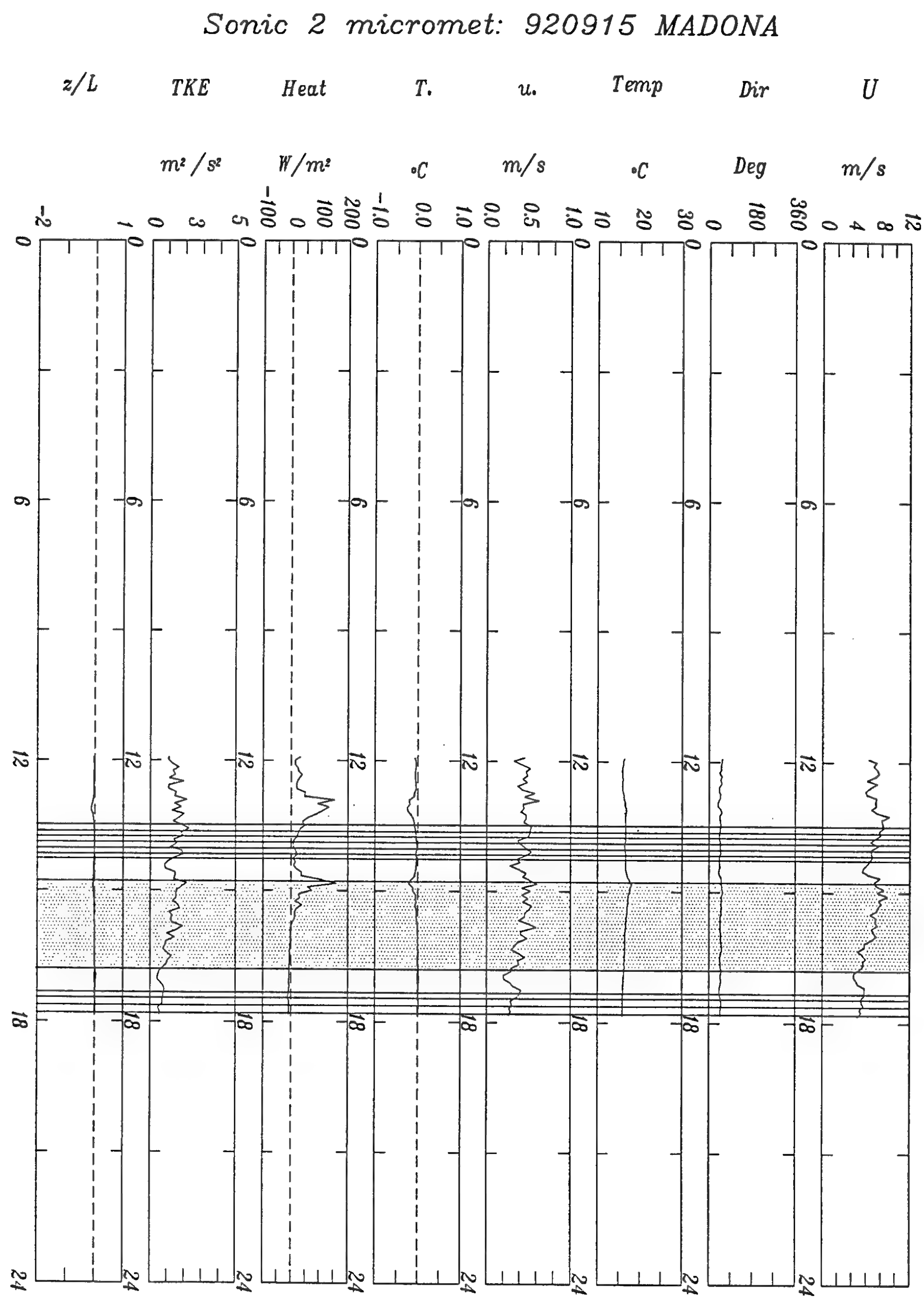
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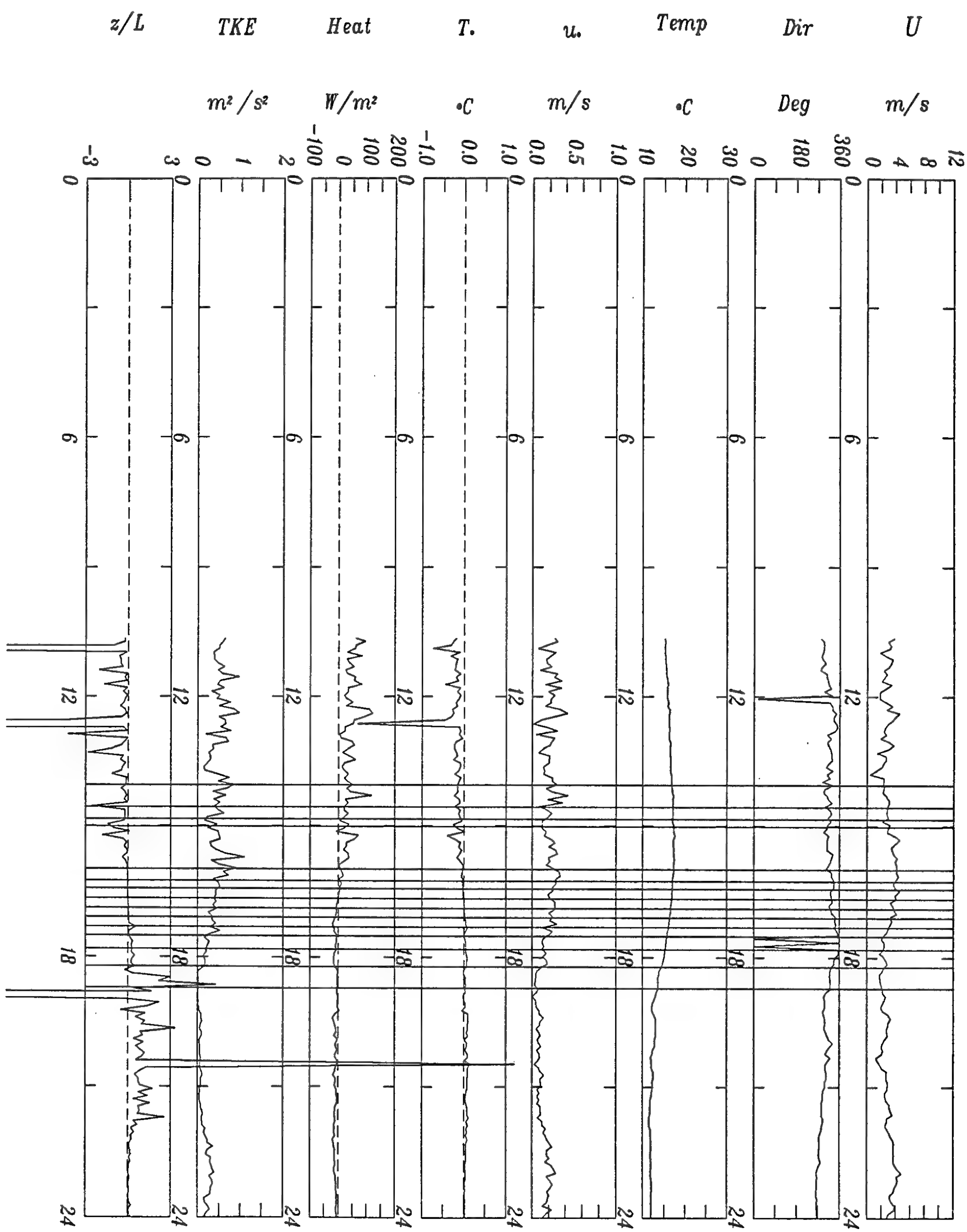

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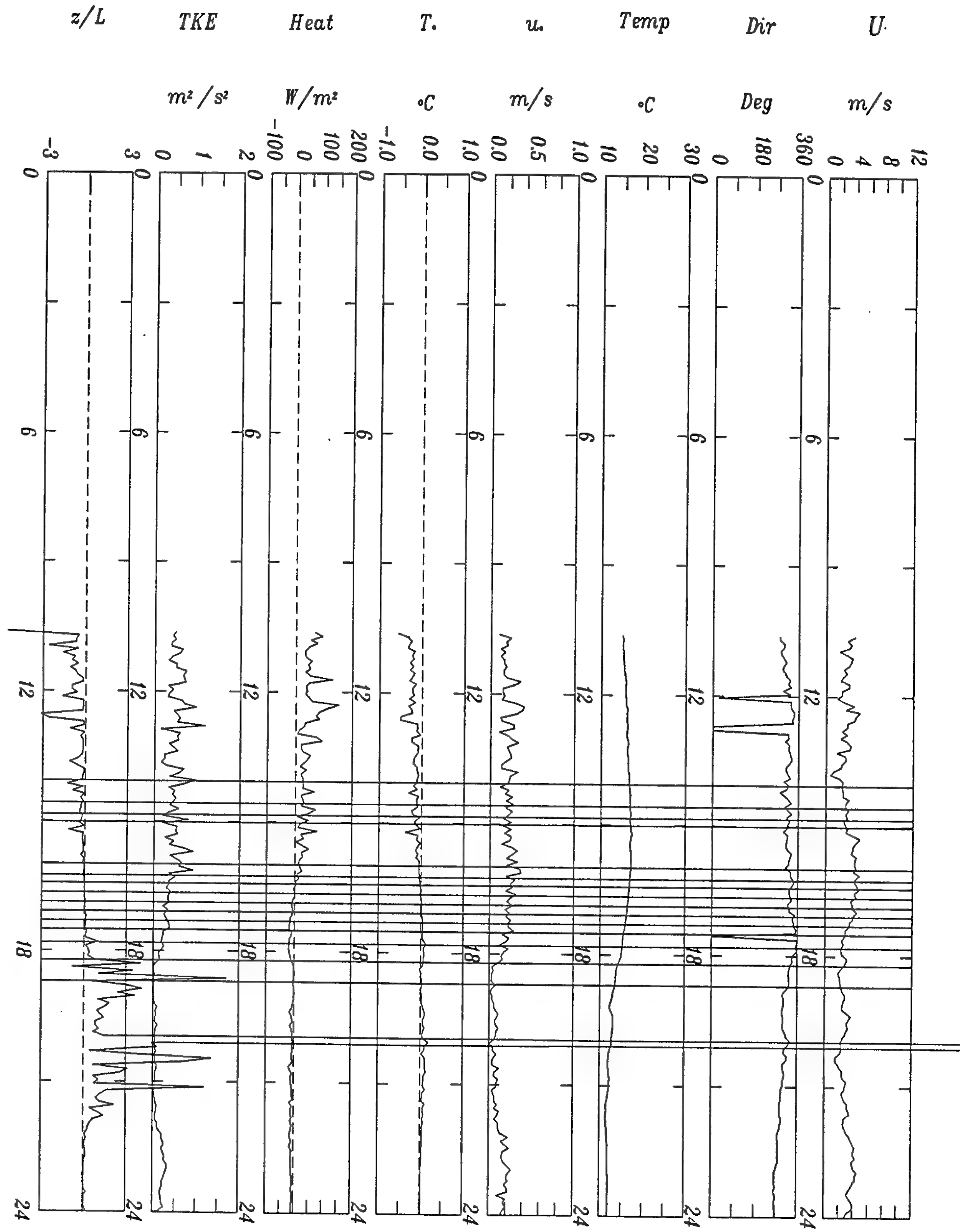

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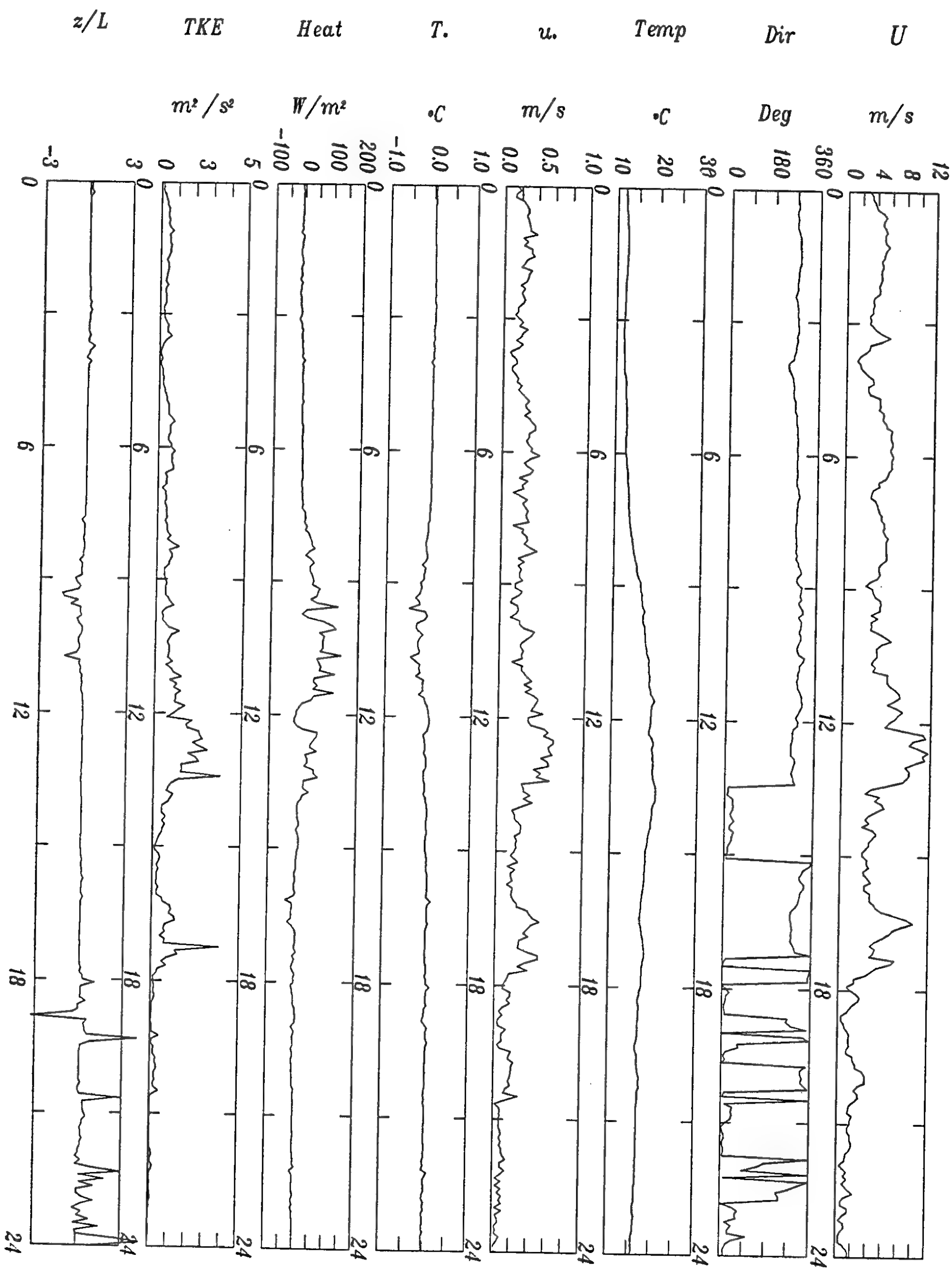

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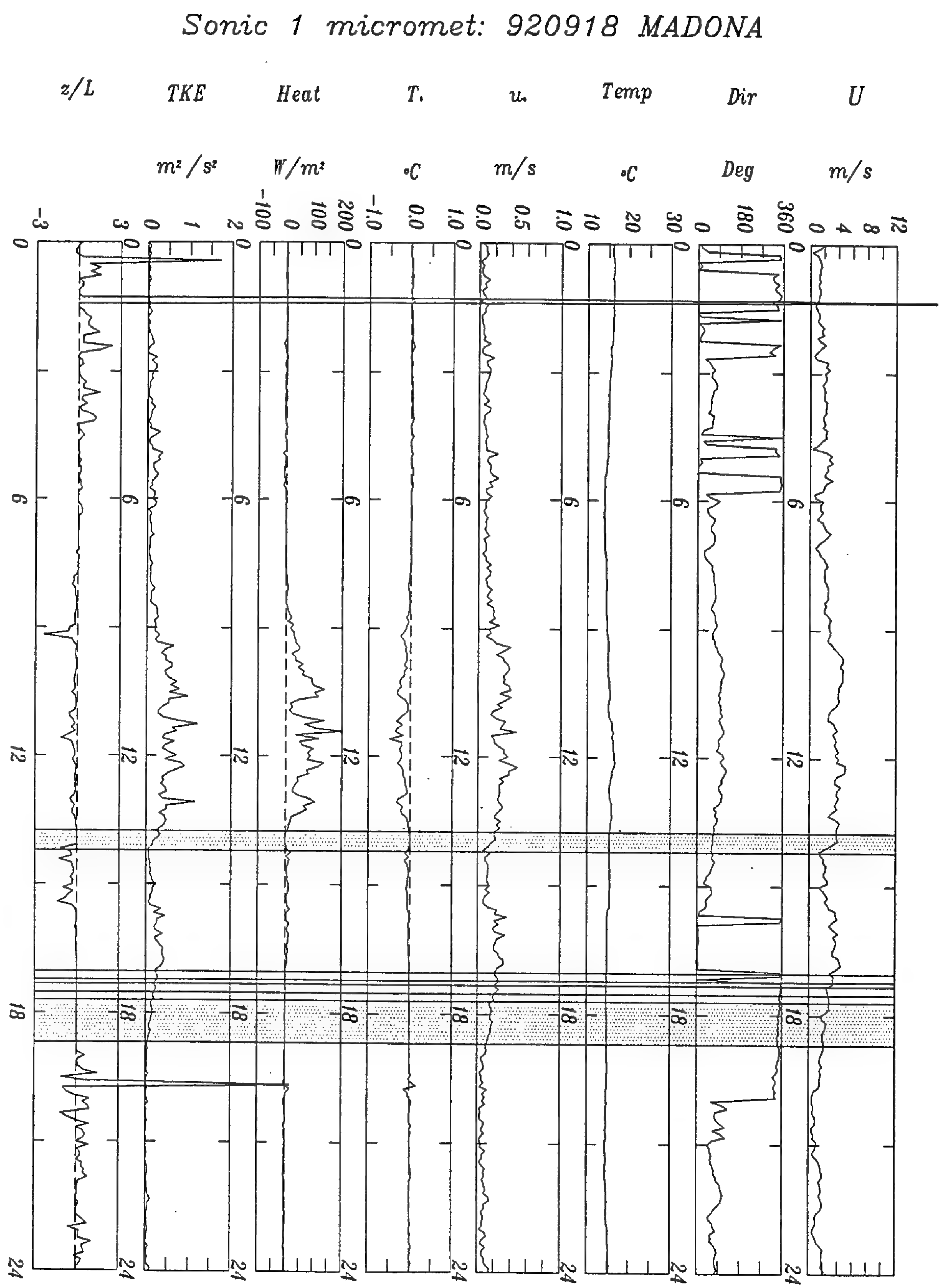
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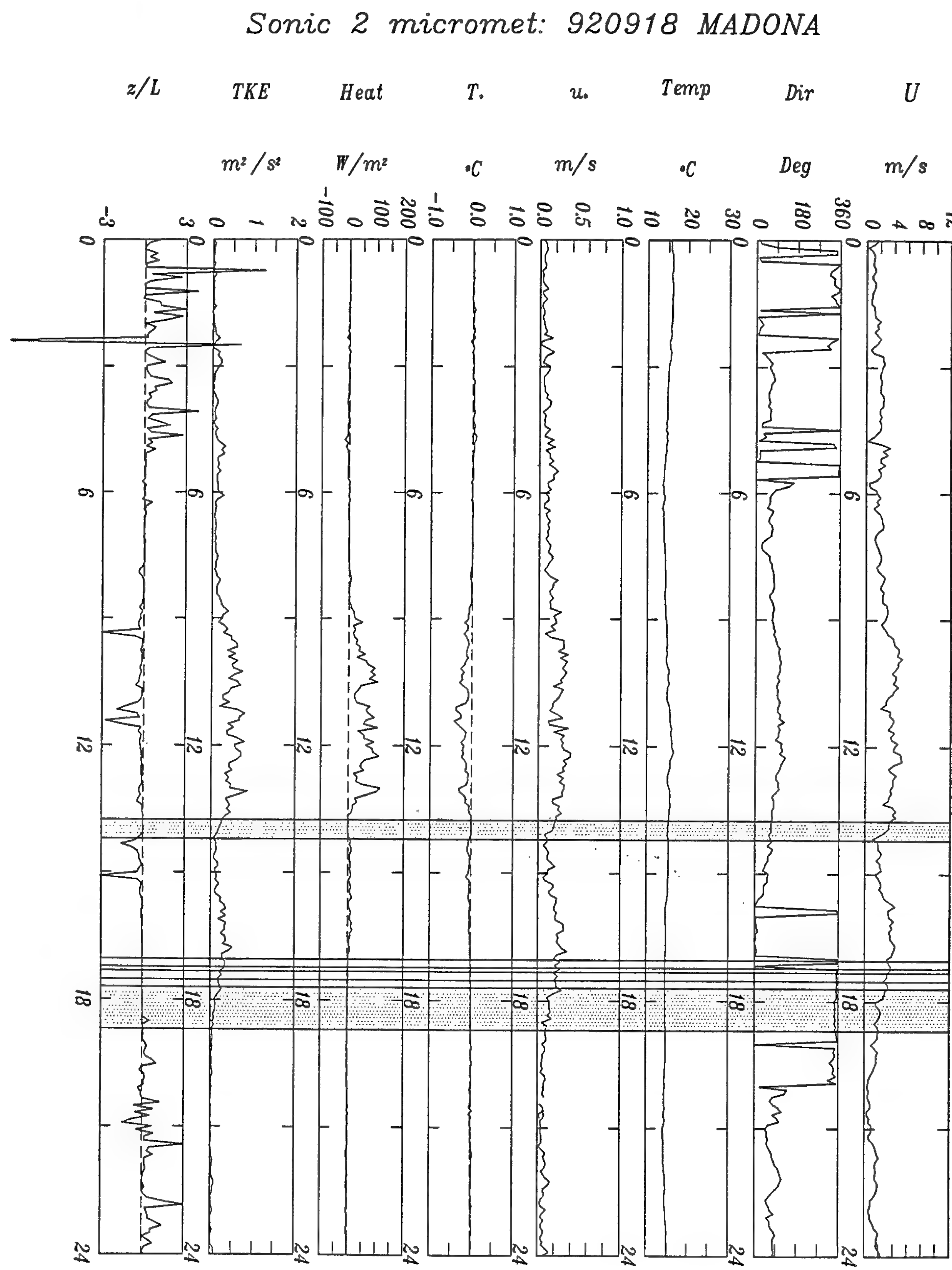

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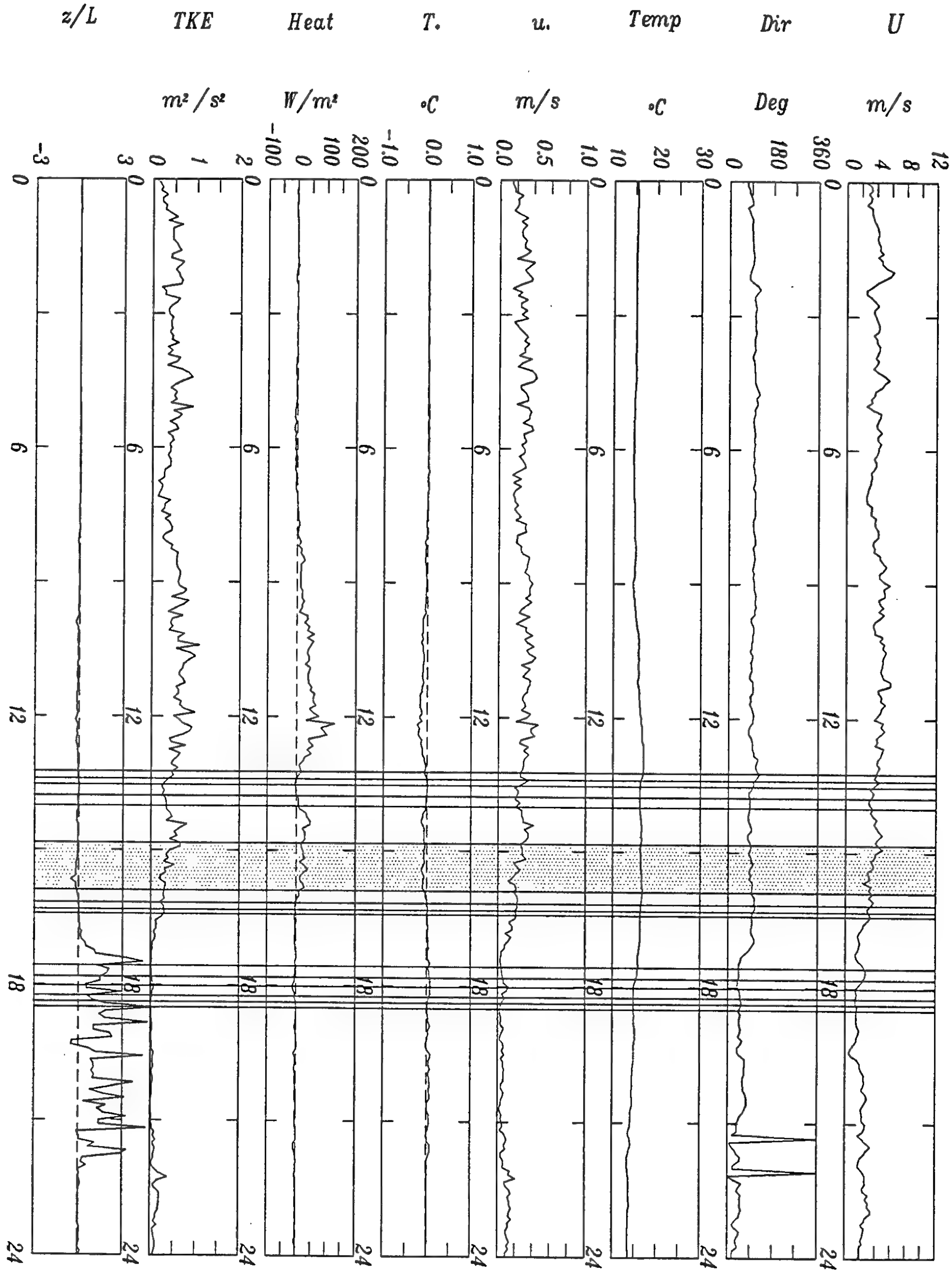
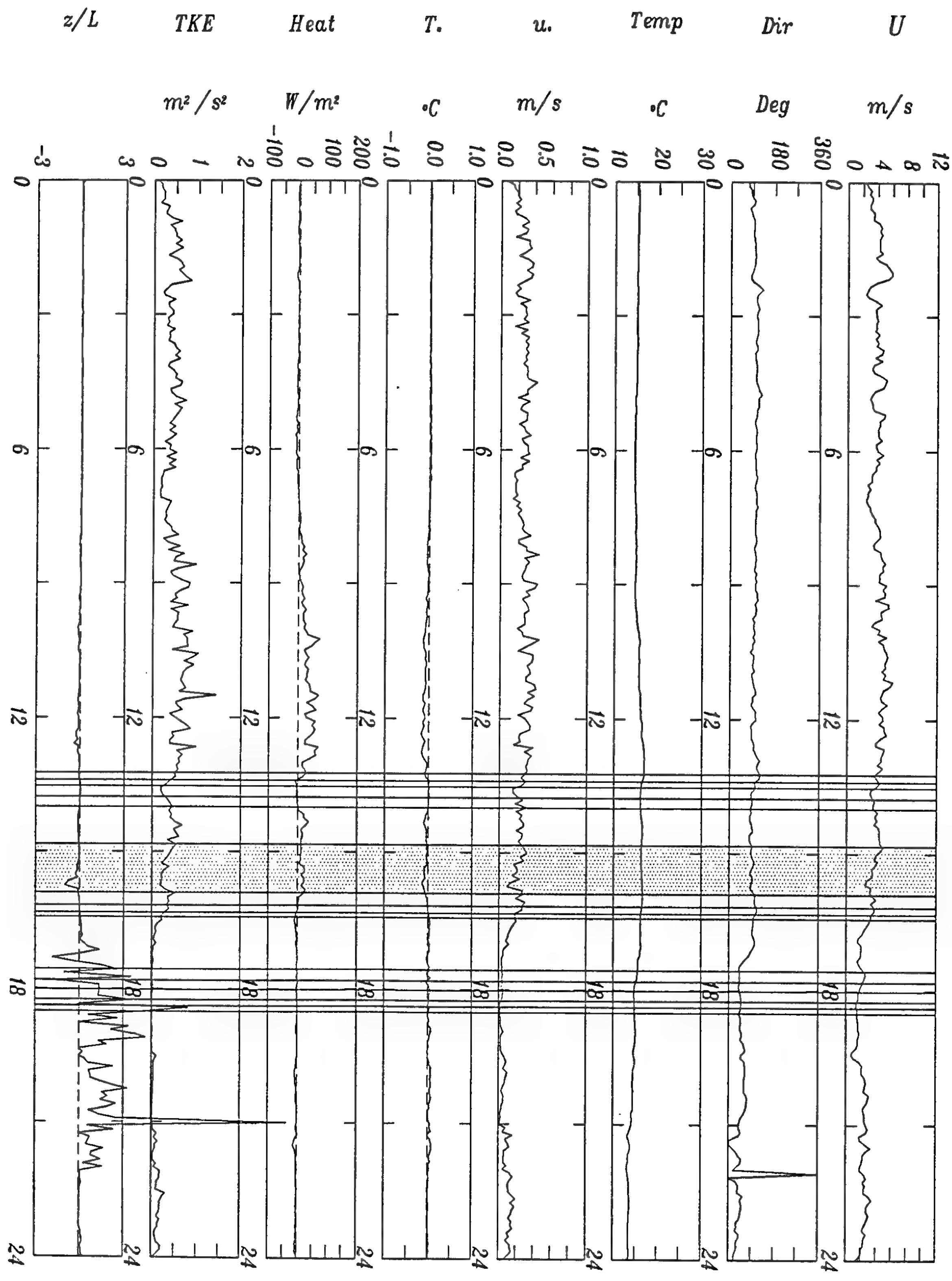


Sonic 2 micromet: 920919 MADONA



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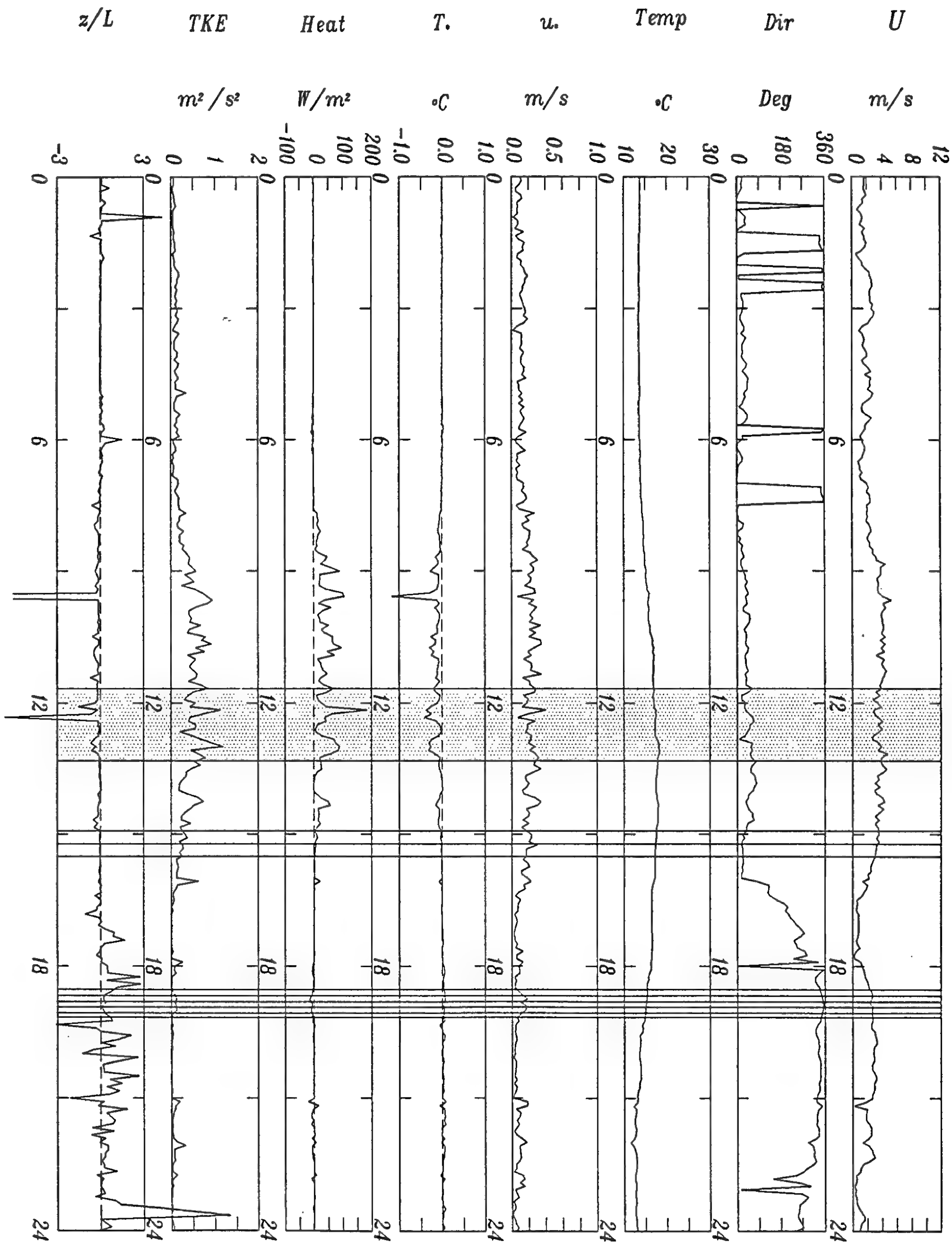
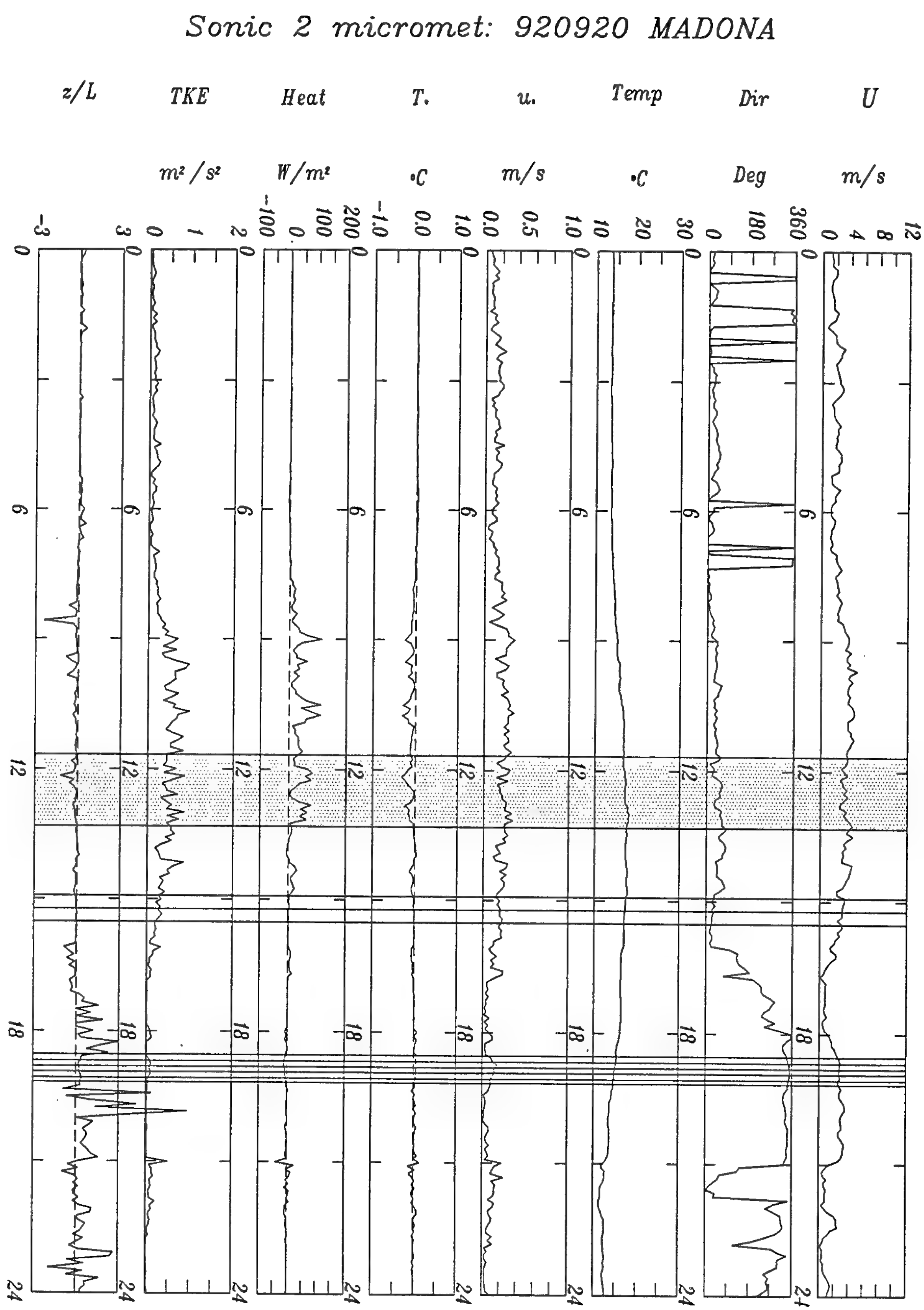
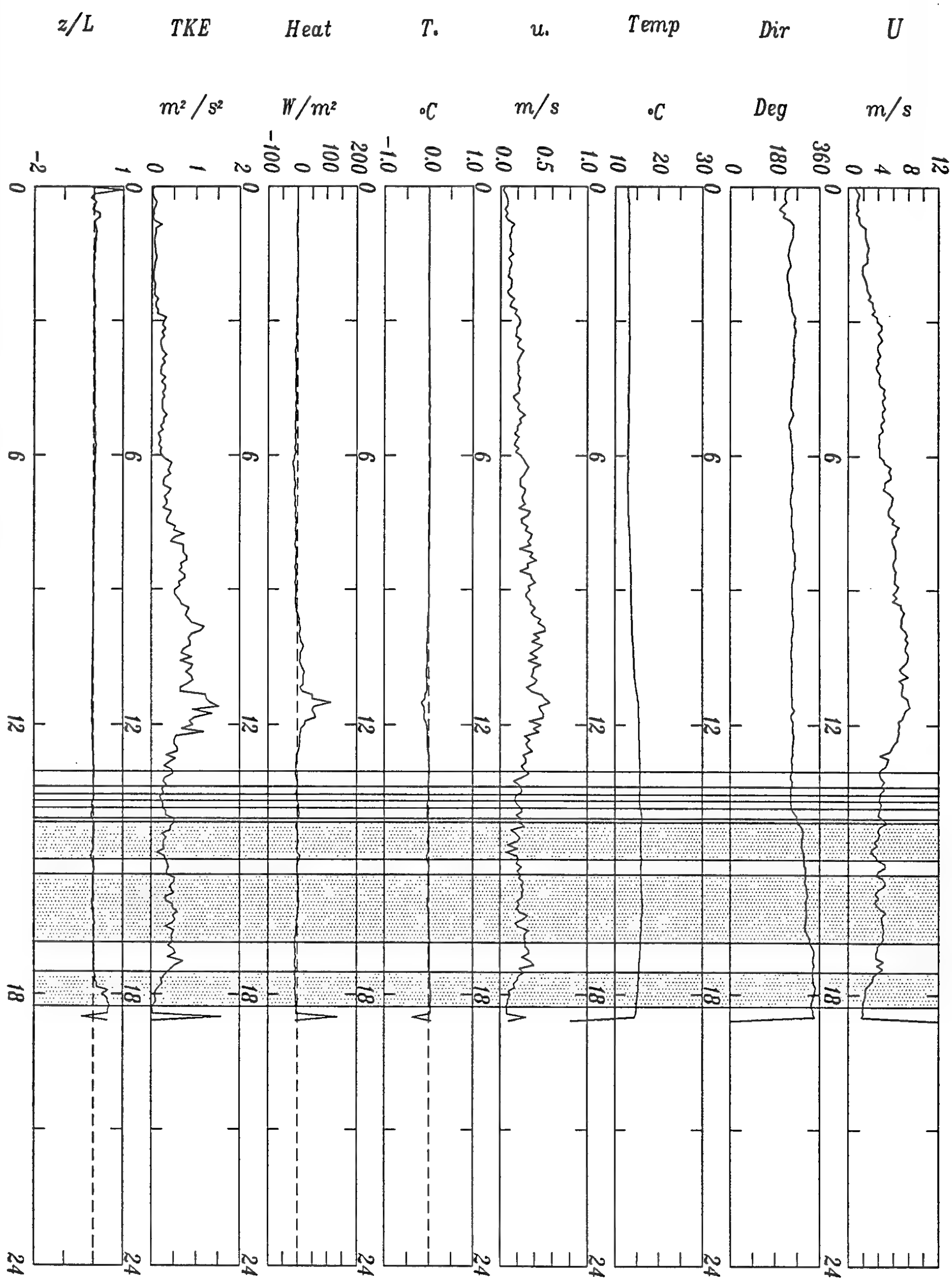



Sonic 2 micromet: 920920 MADONA
z/L
TKE
Heat
T*
u*
Temp
Dir
U
m²/s²
W/m²
°C
m/s
°C
Deg
m/s
0
6
12
18
24

Sonic 1 micromet: 920921 MADONA



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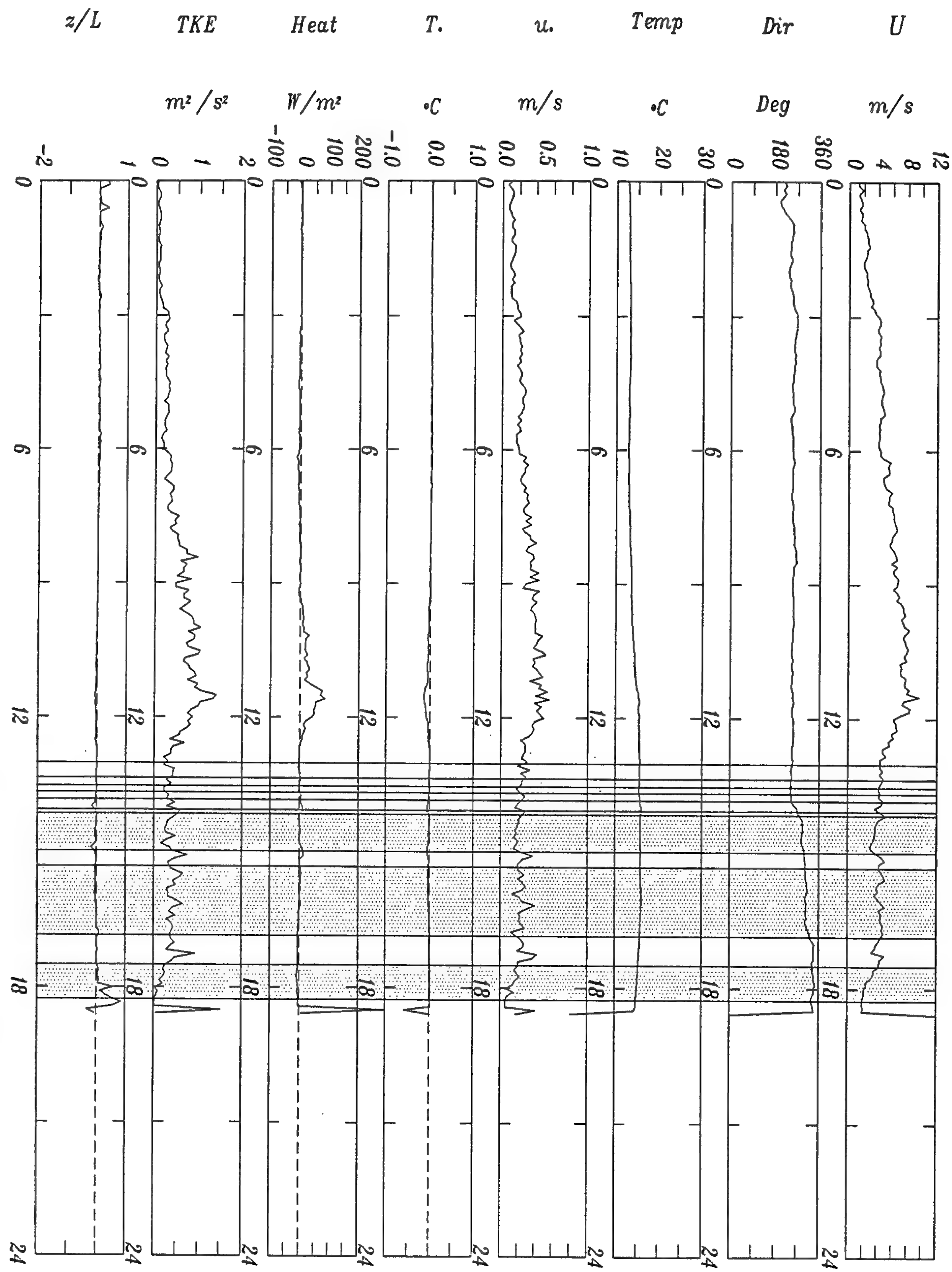

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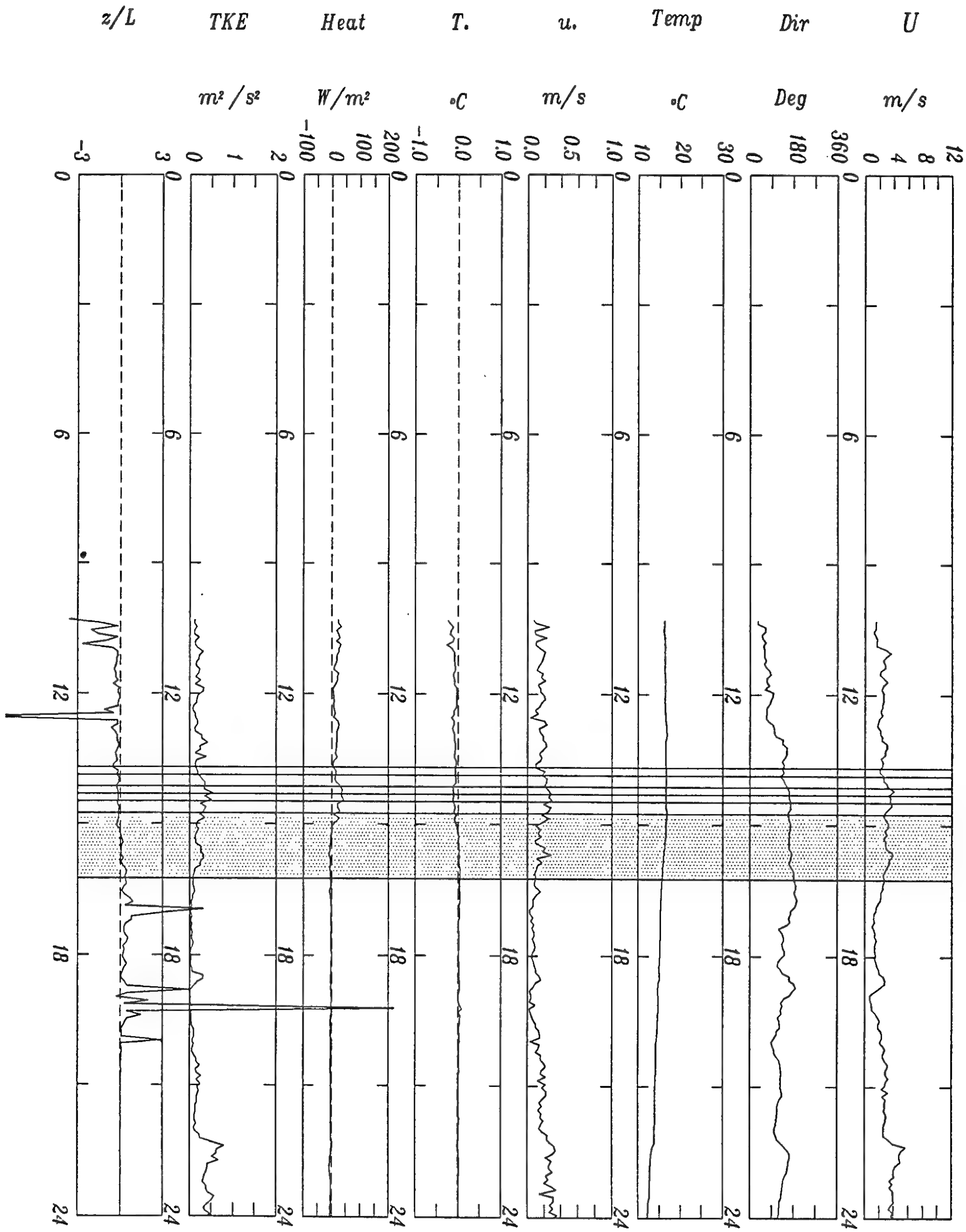
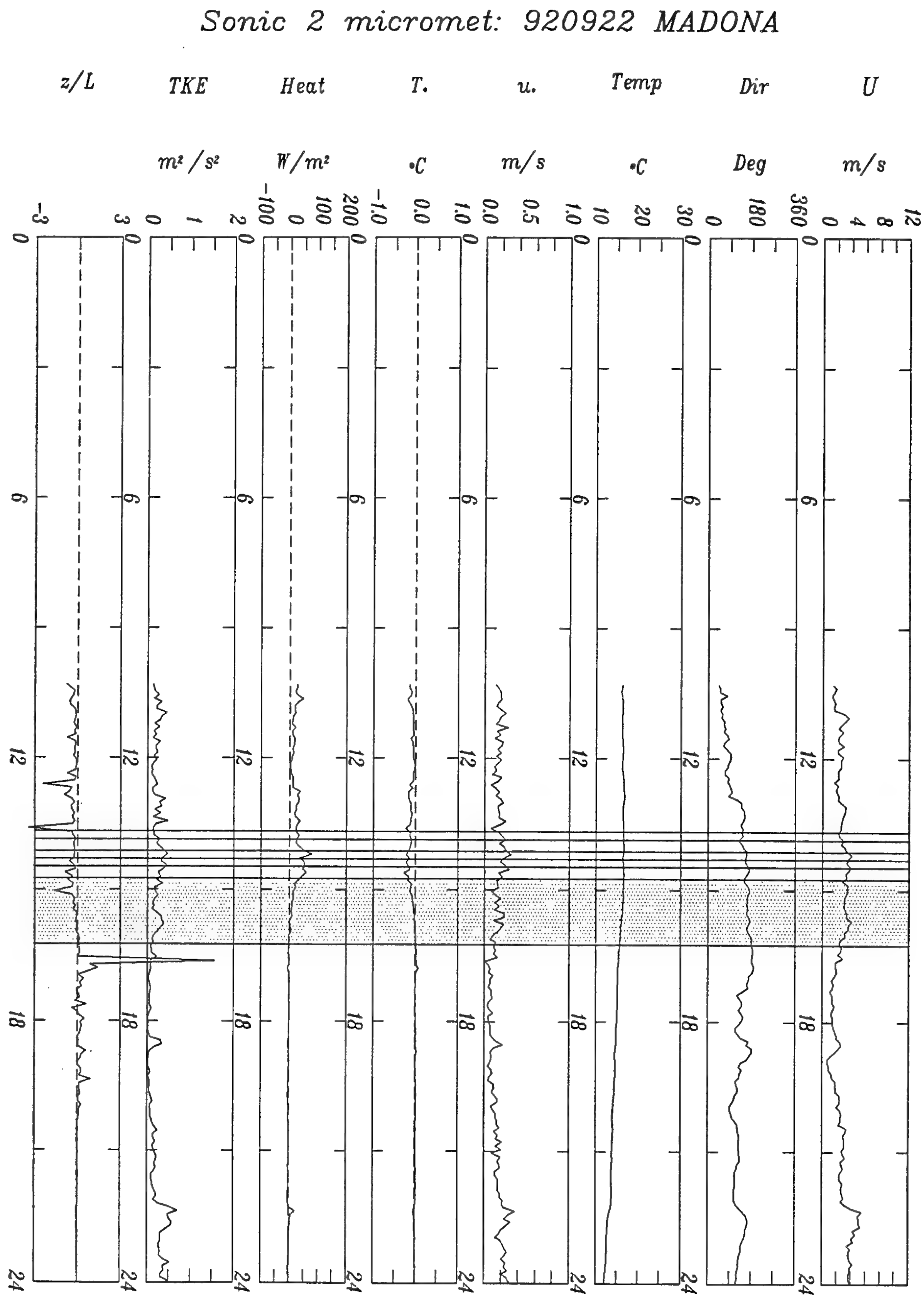
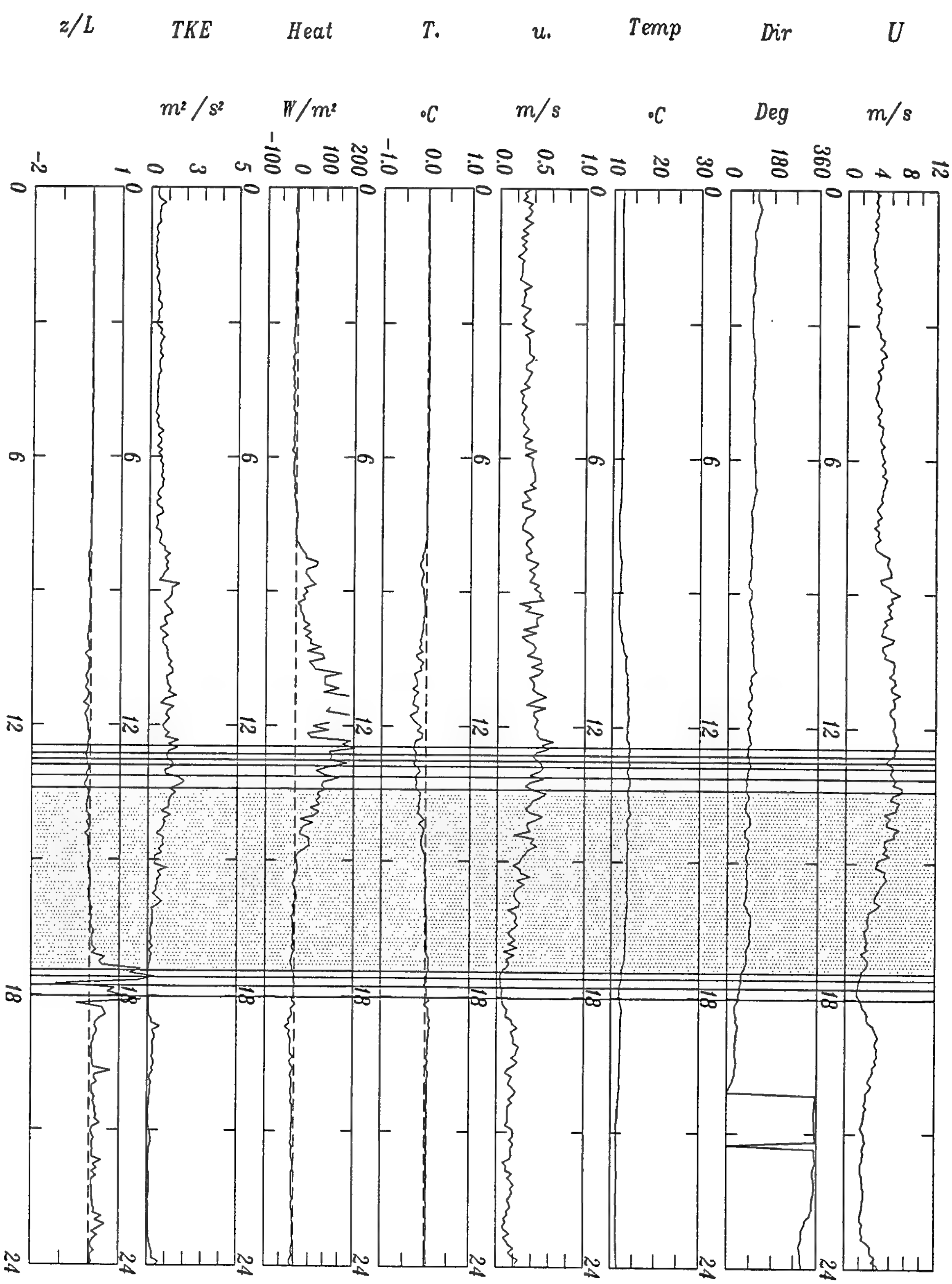



Sonic 2 micromet: 920922 MADONA
z/L
TKE
Heat
T*
u*
Temp
Dir
U
m²/s²
W/m²
°C
m/s
°C
Deg
m/s
0
6
12
18
24

Sonic 1 micromet: 920923 MADONA



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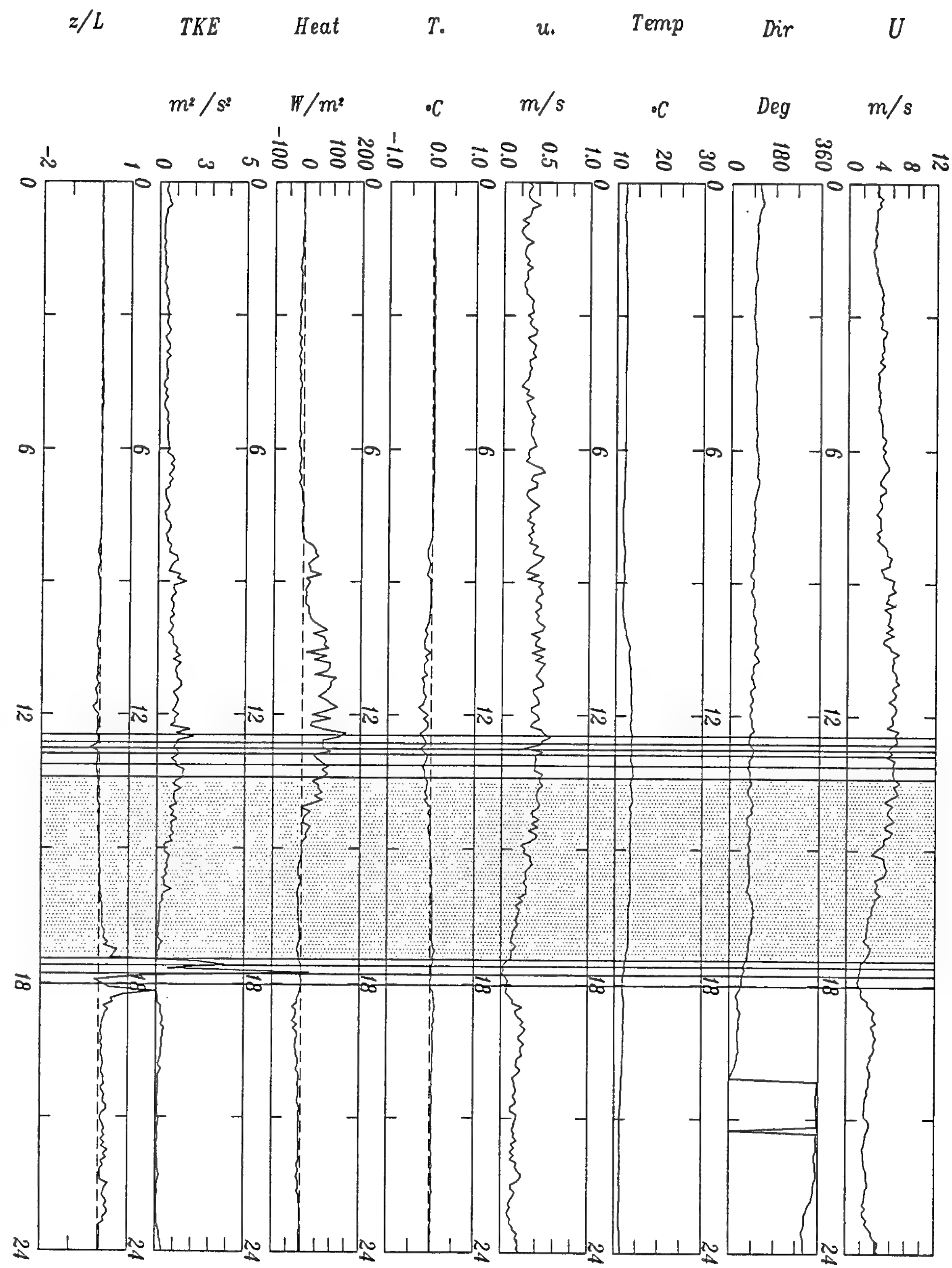
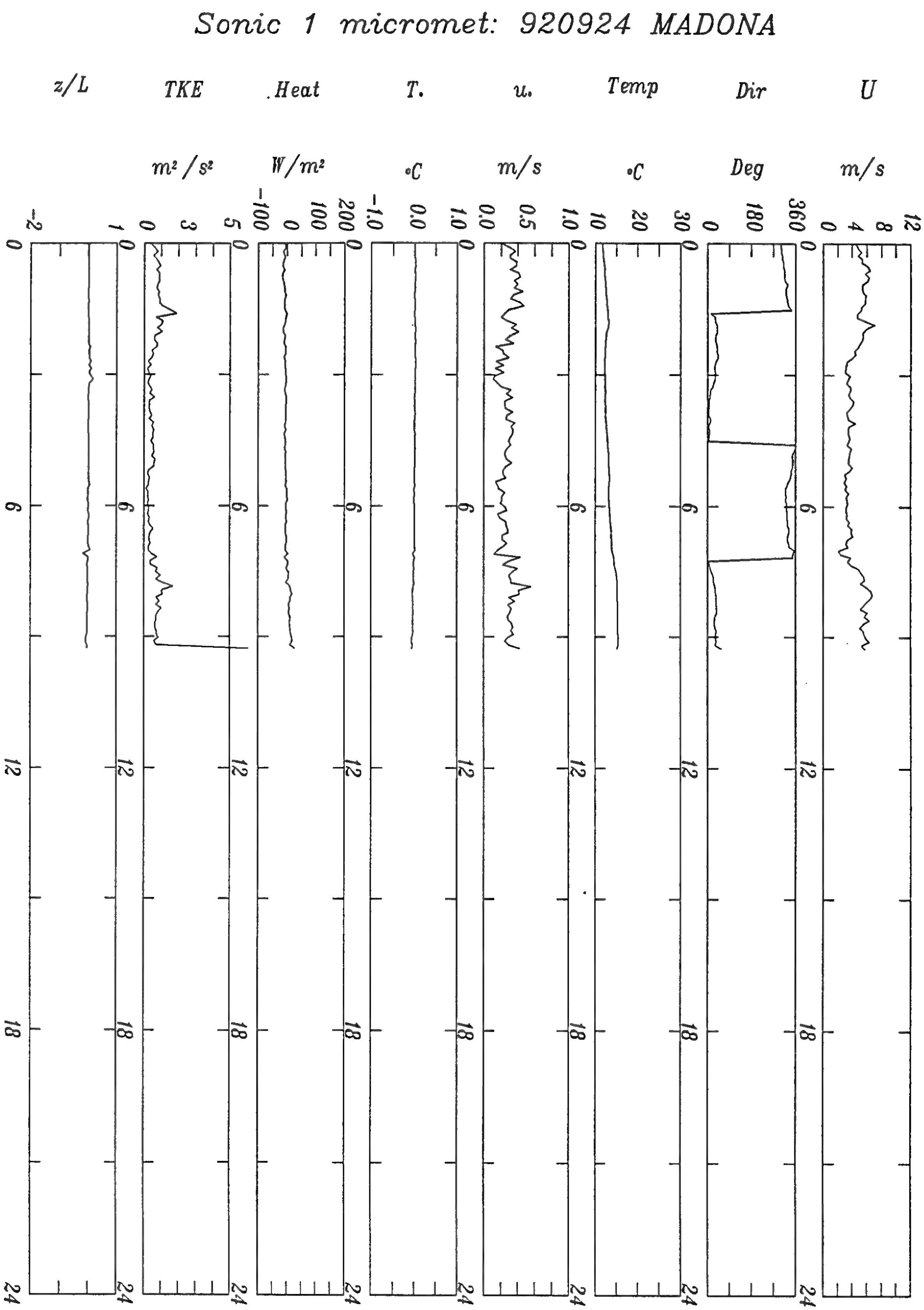
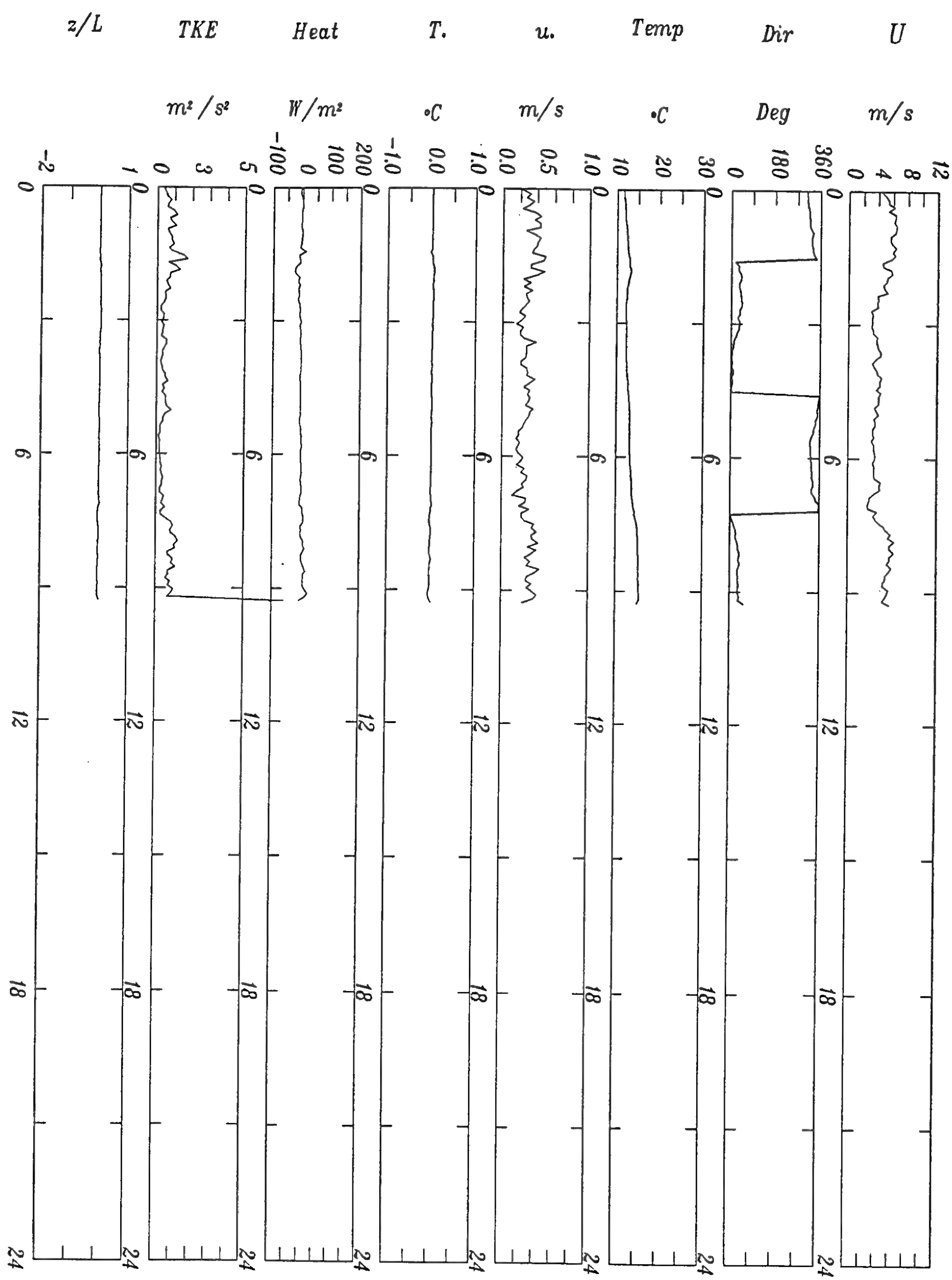
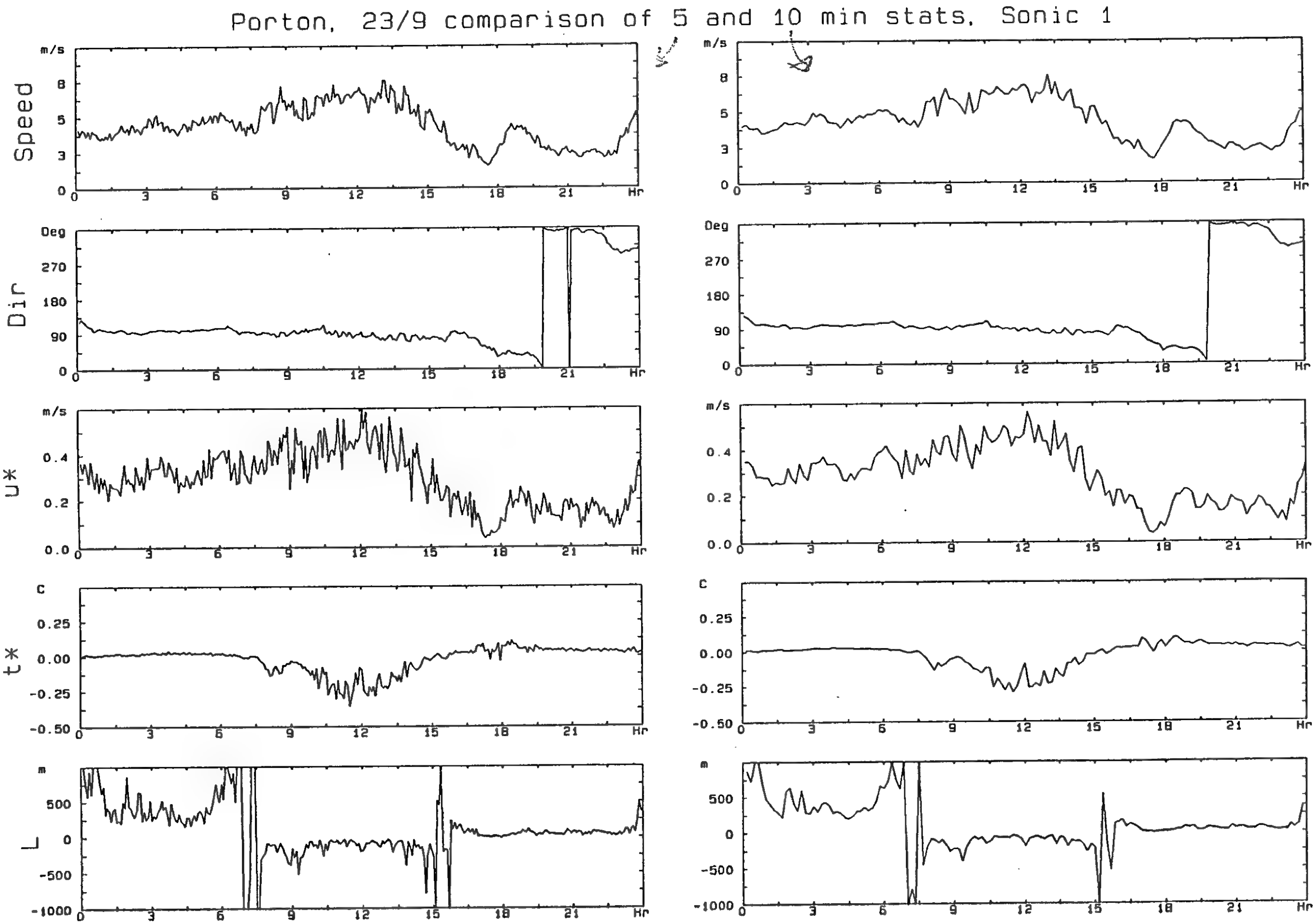


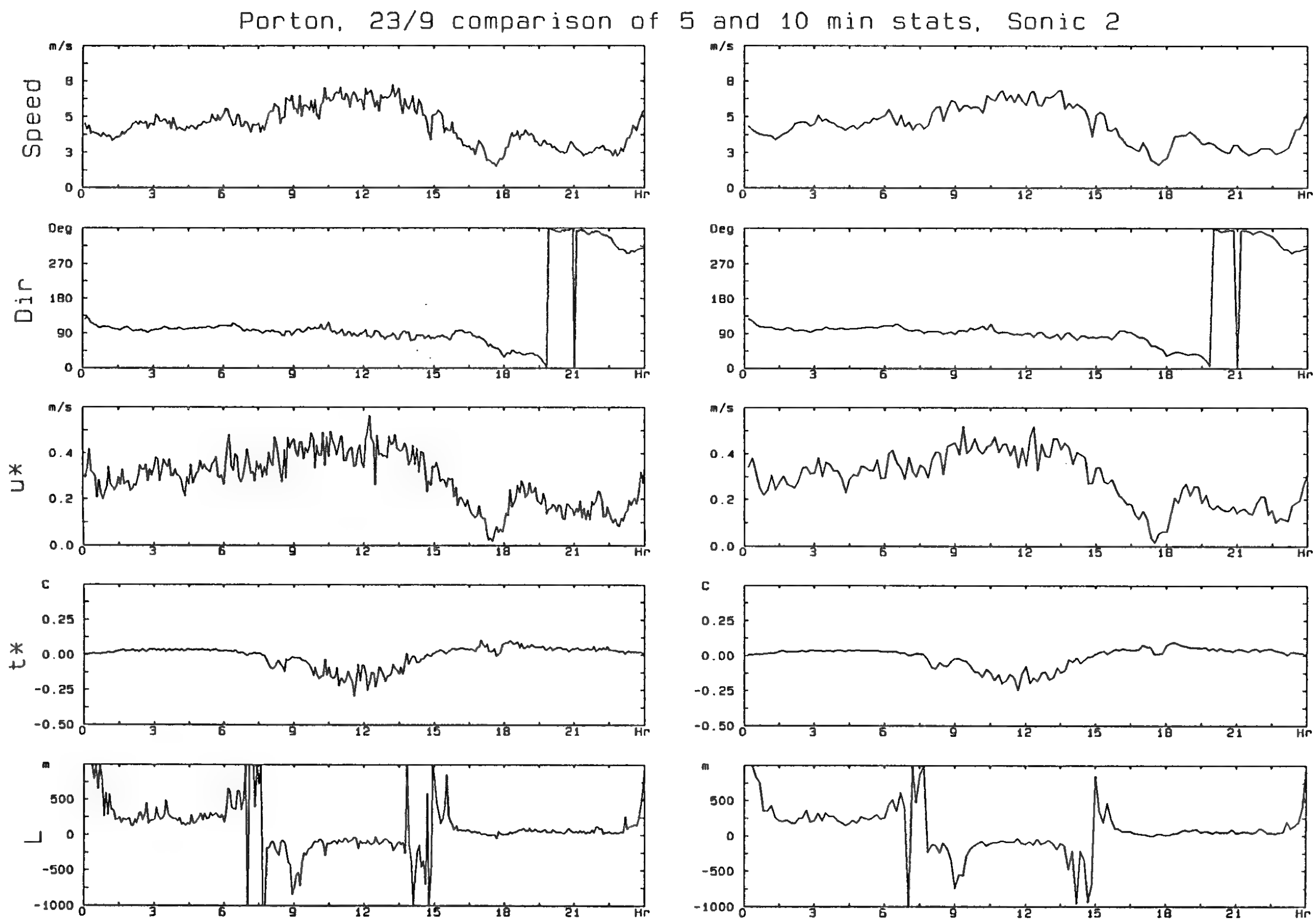

Sonic 1 micromet: 920924 MADONA
z/L
TKE
Heat
T*
u*
Temp
Dir
U
m²/s²
W/m²
°C
m/s
°C
Deg
m/s
-2
1
0
3
5
-100
0
100
200
-1.0
0.0
1.0
0.0
0.5
1.0
10
20
30
0
180
360
0
4
8
12
0
6
12
18
24

Sonic 2 micromet: 920924 MADONA



Appendix II.2





Porton, 23/9 comparison of 5 and 10 min stats, Sonic 2
Speed
Dir
u*
t*
L
m/s
Deg
C
m
Hr

Name	Qua	Type of relase	Time (HMs)	Release heigth (m)	L.s. (m)/deg	Source pos.	Lidar pos
mad14a	+	puff	13:38:30	2.3	3^0	S14-1	L14-1
mad14b	-	---	13:52:00	-	-	--	--
mad14c	-	---	14:00:15	-	-	--	--
mad14d	+	---	14:08:?	-	-	--	--
mad14e	+	---	14:18:15	-	-	--	--
mad14f	-	---	14:28:30	-	0^0	--	--
mad14g	+	puff	14:54:?	2.3	-	S14-2	--
mad14h	+	cont	15:29-16:11	1.0	-	S14-3	L14-3
mad14i	+	----	16:14-16:33	-	-	--	--
mad14j	+	----	16:35-16:43	-	-	--	--
mad14k	+	----	16:47-17:43	-	-	--	--
mad15a	+	puff	13:29:00	2.9	-	S15-1	L15-1
mad15b	+	---	13:38:50	-	-	--	--
mad15c	+	---	13:45:17	-	-	--	--
mad15d	+	---	13:53:00	-	-	--	--
mad15e	+	---	14:01:30	-	-	--	--
mad15f	+	---	14:09:00	-	-	--	--
mad15g	+	---	14:15:30	-	-	--	--
mad15h	+	cont	15:00-15:14	1.0	-	--	--
mad15i	+	----	15:16-15:43	-	-	--	--
mad15j	+	----	15:46-16:10	-	-	--	--
mad15k	+	----	16:13-16:30	-	-	--	--
mad15l	+	----	16:33-16:39	-	-	--	--
						--	--
mad15m	+	puff	17:19:00	2.9	-	--	--
mad15n	+	---	17:48:10	-	-	--	--

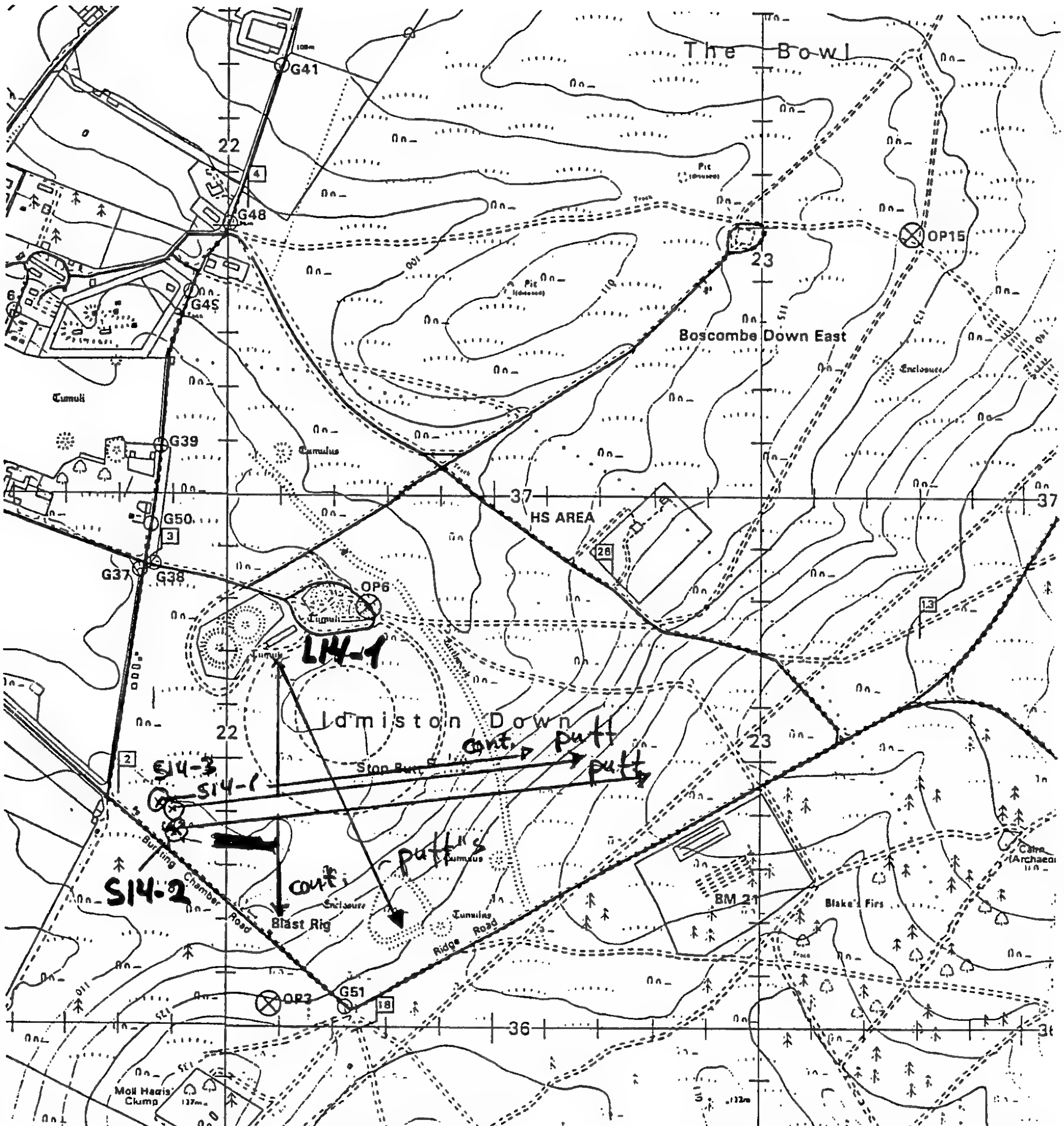
Name	Qua	Type of relase	Time (HMs)	Release heigth (m)	L.s. (m)/deg	Source pos.	Lidar pos
mad14a	+	puff	13:38:30	2.3	3^0	S14-1	L14-1
mad16a	+	puff	14:04:00	1.0	-8m oT.	S16-1	L16-1
mad16b	+	---	14:34:45	-	--	--	--
mad16c	-	---	14:51:20	-	--	--	--
mad16d	+	---	15:02:10	-	--	--	--
mad16e	-	---	16:00:00	-	--	--	--
mad16f	+	---	?16:15:30	-	--	--	--
mad16g	+	---	16:26:00	-	--	--	--
mad16h	+	---	16:39:15	-	--	--	--
mad16i	+	---	16:52:15	-	--	--	--
mad16j	+	---	17:04:30	-	--	--	--
mad16k	+	---	17:18:00	-	--	--	--
mad16l	+	---	17:30:00	-	--	--	--
mad16m	+	---	17:48:45	-	--	--	--
mad16n	+	---	18:12:50	-	--	--	--
mad16o	+	---	18:42:32	-	--	--	--
mad18a	+	cont	17:56-18:37	1.0	$1\text{-}2^0$	S18-1	L18-1
mad19a	+	puff	13:15:00	6.0	$2\text{-}3^0$	S19-1	L19-1A
mad19b	+	---	?13:25:00	-	--	--	--
mad19c	+	---	13:36:00	-	--	--	--
mad19d	-	---	13:47:23	-	--	--	--
mad19e	+	cont	15:09-15:52	1.0	3^0	S19-1	L19-1
mad19f	-	puff	16:10:40	6.0	--	--	L19-2
mad19g	+	---	16:26:35	-	--	--	--
mad19h	+	---	17:49:30	-	5m oT	S19-3	L19-2

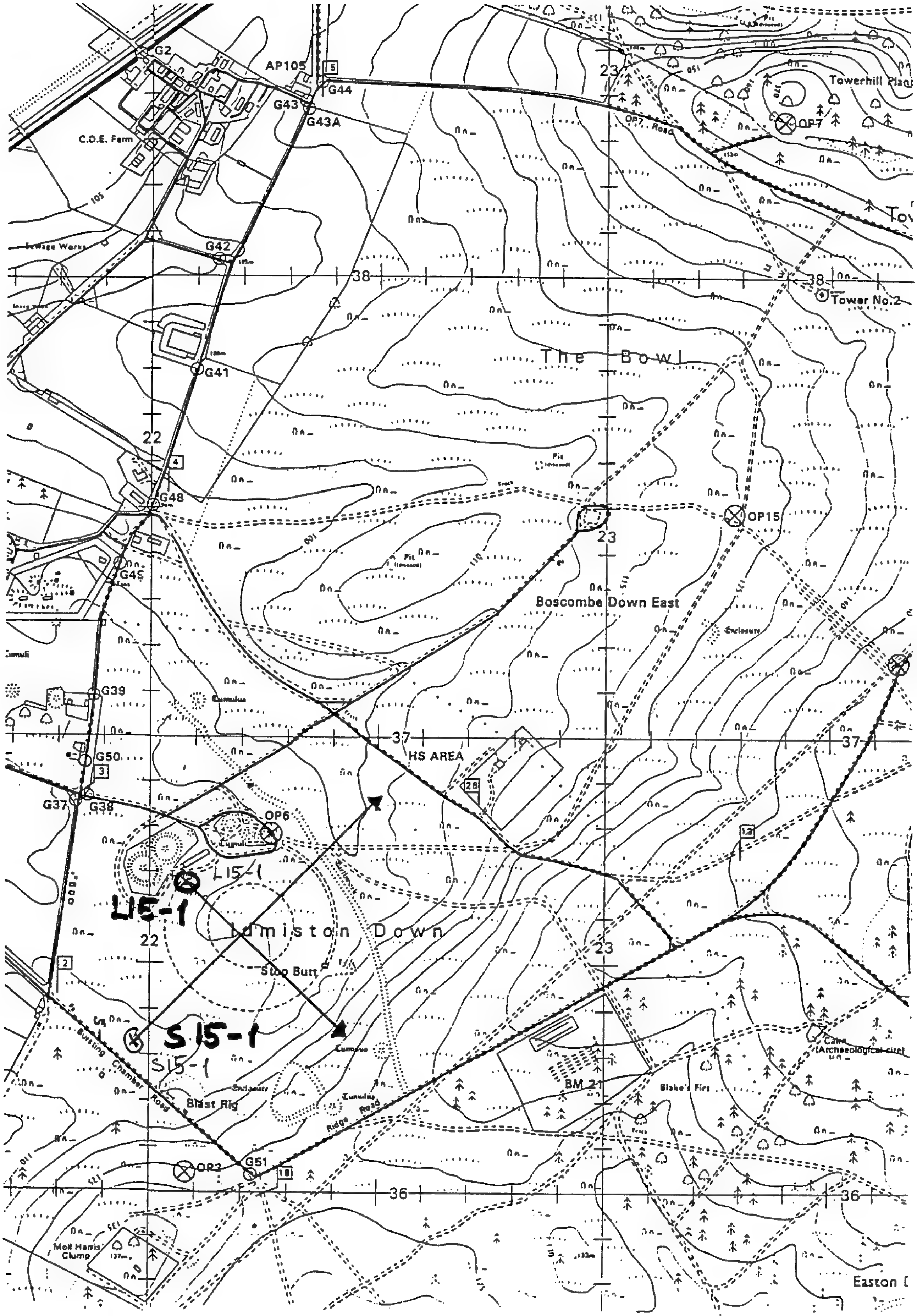
Name	Qua	Type of relase	Time (HMs)	Release heigth (m)	L.s. (m)/deg	Source pos.	Lidar pos
mad14a	+	puff	13:38:30	2.3	3^0	S14-1	L14-1
mad19i	+	---	18:01:00	-	--	--	--
mad19j	+	---	18:14:30	-	--	--	--
mad19k	+	---	18:23:00	-	--	--	--
mad19l	+	---	18:30:00	-	--	--	--
mad20a	-	cont	12:07-12:29	1.0	2m oT	S20-1	L20-1
mad20b	(-)	---	12:47-13.01	-	--	--	--
mad20c	+	puff	14:55:22	6.0	2m oT	S20-2	L20-2
mad20d	-	---	15:13:30	-	--	--	--
mad20e	-	---	15:30:00	-	--	--	--
mad20f	-	---				S20-3	L20-3
mad20g	-	---				--	--
mad20h	-	---				--	--
mad20i	-	---				--	--
mad20j	+	---	18:32:00	1.0	--	--	--
mad20k	+	---	18:41:00	-	--	--	--
mad20l	+	---	18:49:00	-	--	--	--
mad20m	+	---	18:56:00	-	--	--	--
mad20n	+	---	19:04:00	-	--	--	--
mad20o	+	---	19:10:00	-	--	--	--
mad21a	+	puff	13:22:30	1.0	0^0	S21-1	L21-1
mad21b	+	---	13:32:40	-	--	--	--
mad21c	+	---	13:41:30	-	--	--	--
mad21d	+	---	13:51:20	-	--	--	--
mad21e	+	---	14:04:30	-	--	--	--

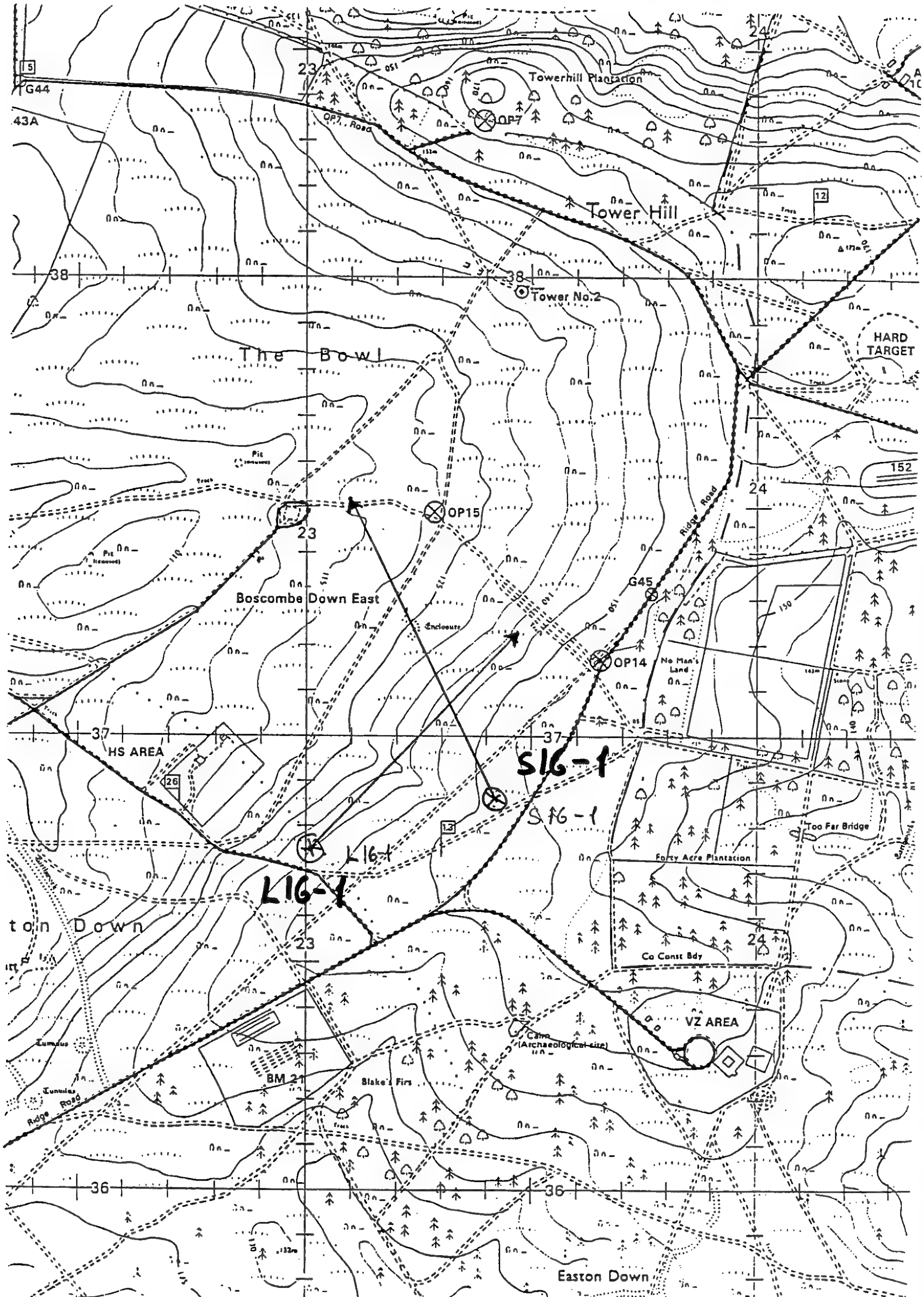
Name	Qua	Type of relase	Time (HMs)	Release heigth (m)	L.s. (m)/deg	Source pos.	Lidar pos
mad14a	+	puff	13:38:30	2.3	3^0	S14-1	L14-1
mad21f	(+)	cont	14:42-14:59	1.0	0^0	S21-2	L21-2
mad21g	+	cont	15:19-15:43	-	--	--	L21-3
mad21h	(+)	---	15:45-16:17	-	--	--	--
mad21i	(-)	---	16:18-16:40	-	--	--	--
mad21j	-	---	(-)	-	--	--	--
mad21k	++	cont	17:31-18:19	1.0	--	S21-4	L21-4
mad22a	+	puff	13:41:25	2.3	--	S22-1	L22-1
mad22b	+	---	13:52:13	-	--	--	--
mad22c	+	---	14:07:45	-	--	--	--
mad22d	+	---	14:18:35	-	--	--	--
mad22e	+	---	14:29:00	-	--	--	--
mad22f	+	cont	14:51-16:13	1.0	scan	S22-2	--
mad23b	(-)	puff	12:38:30	2.3	2m oT	S23-1	L23-1
mad23c	(+)	---	12:46:30	-	--	--	--
mad23d	(-)	---	12:54:00	-	--	--	--
mad23e	(-)	---	13:08:30	-	--	--	--
mad23f	+	cont	13:32-14:46	1.0	scan	S23-2	--
mad23g	+	---	15:00-17:31	-	--	--	--
mad23h	+	puff	17:36:30	2.3	2m oT	S23-1	--
mad23i	+	---	17:47:30	-	--	--	--

Appendix III.1

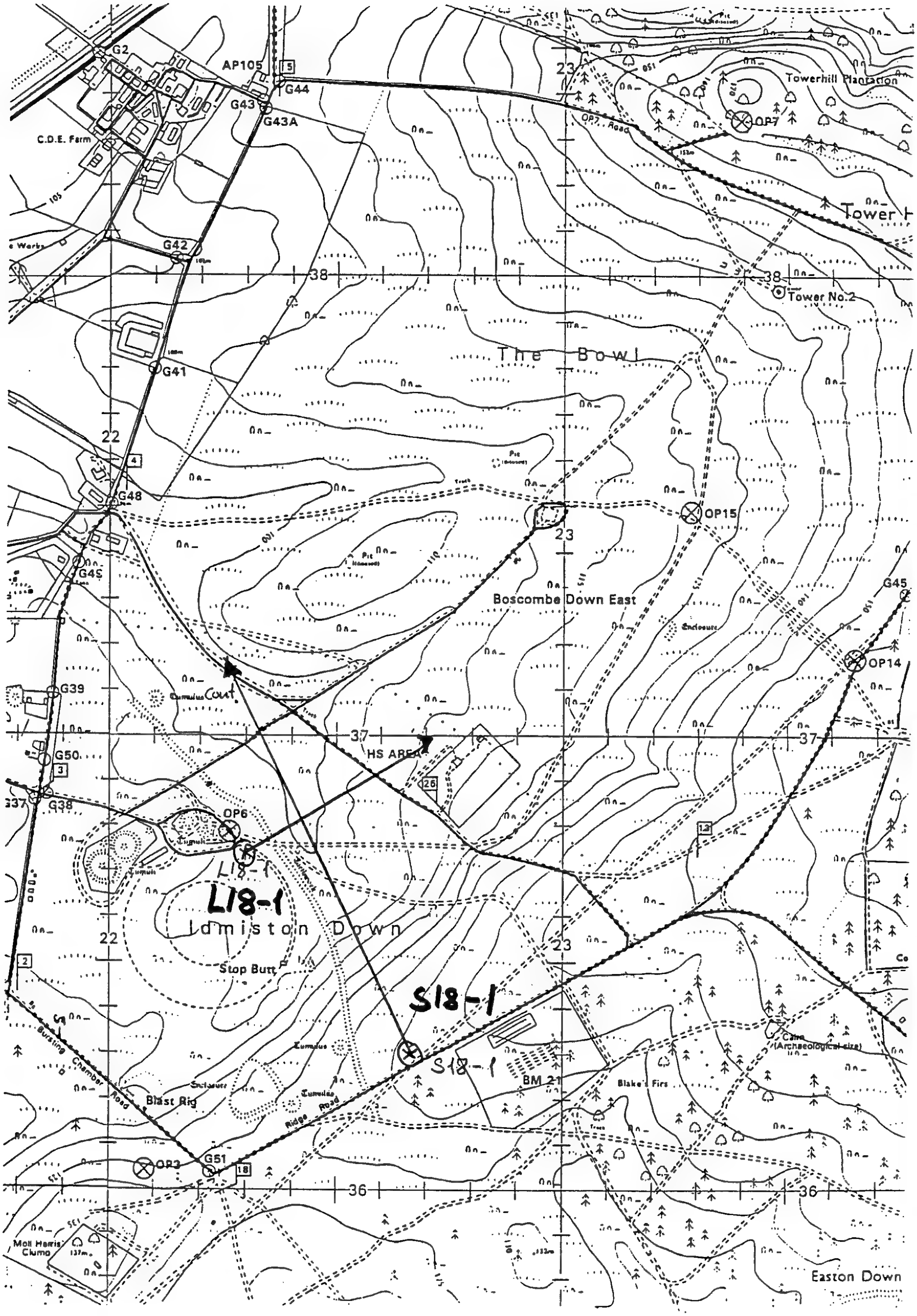
Table III.1b



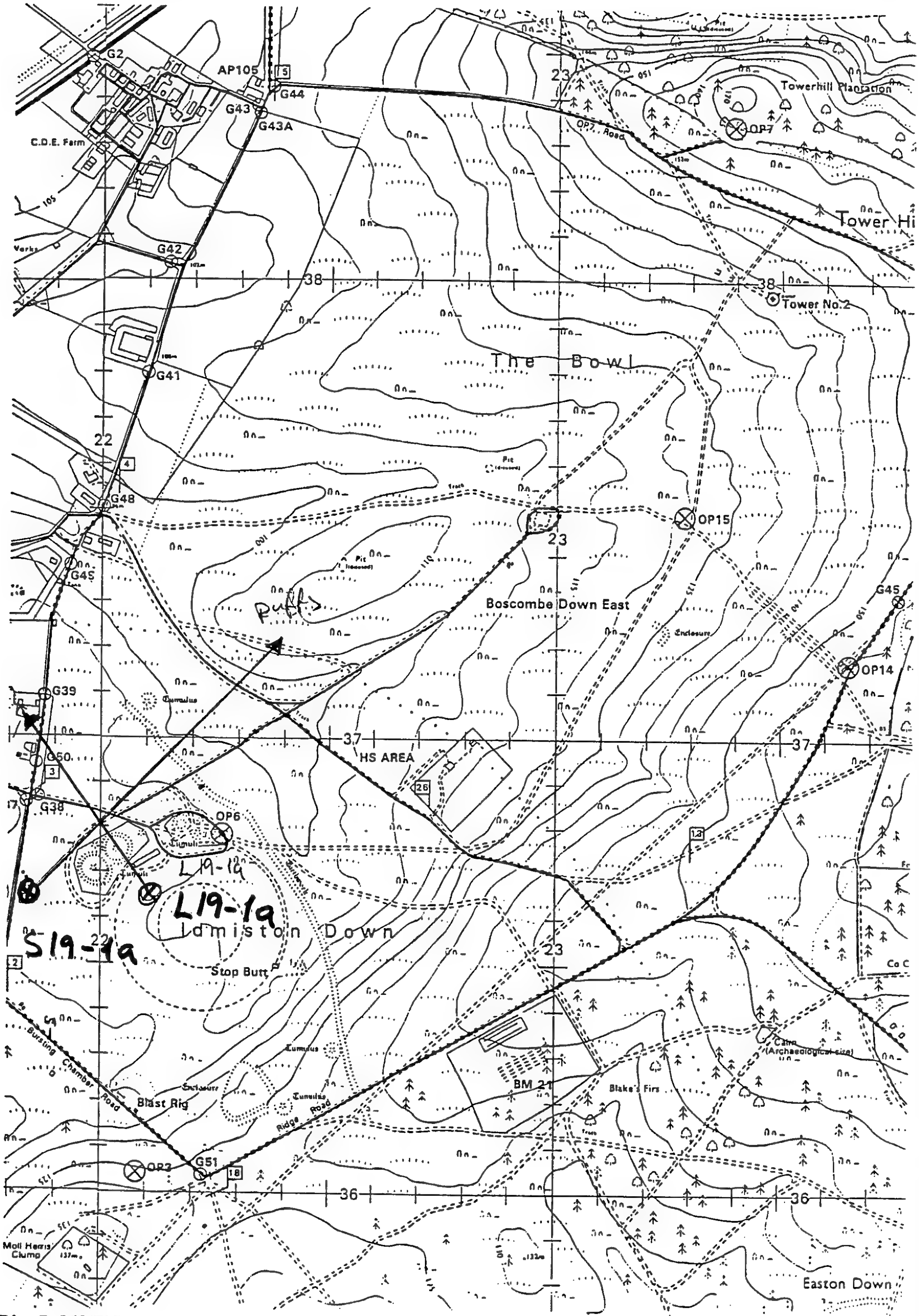

G2
AP105
G44
G43
G43A
C.D.E. Farm
Sewage Works
G42
38
Towerhill Plant
OP7
Tower No.2
The Bowl
G41
22
G48
OP15
23
G49
Boscombe Down East
Enclosure
G39
Tumulus
37
G50
HS AREA
G37
G38
OP6
Tumuli
L15-1
LIE-1
Idmiston Down
Stop Butt
S15-1
Tumulus
Bursting Chamber Road
Blast Rig
Ridge Road
BM 21
Blake's Firs
Cairn (Archaeological site)
OP3
G51
36
Moll Harris' Clump
Easton

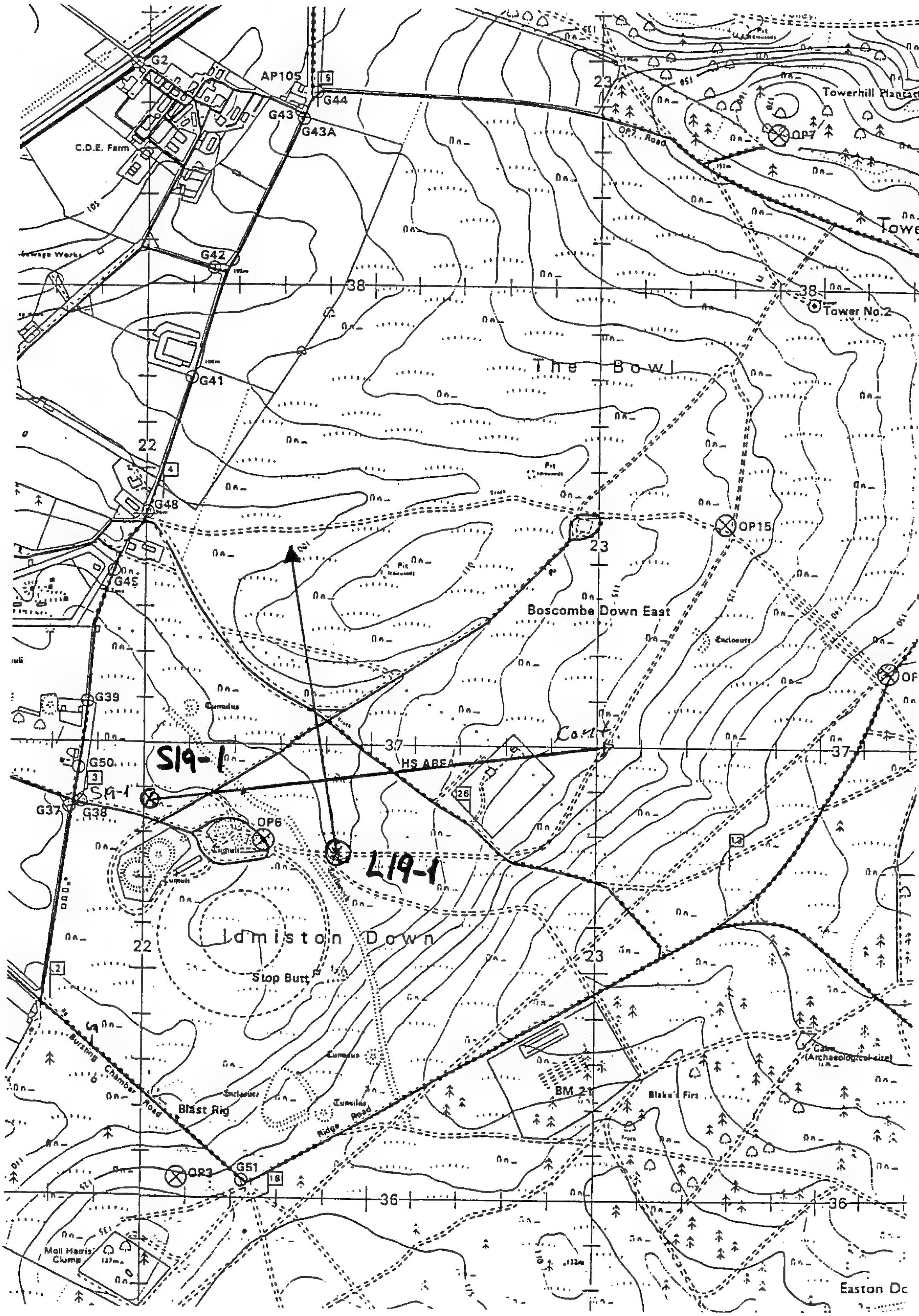


Towerhill Plantation
OP7
OP7 Road
Tower Hill
Tower No.2
The Bowl
HARD TARGET
152
OP15
Boscombe Down East
Enclosure
Ridge Road
G45
OP14
No Man's Land
HS AREA
S16-1
L16-1
Too Far Bridge
Forty Acre Plantation
Co Const Bdy
VZ AREA
Cairn (Archaeological site)
BM 21
Blake's Firs
Tumulus
ton Down
Easton Down
G44
43A

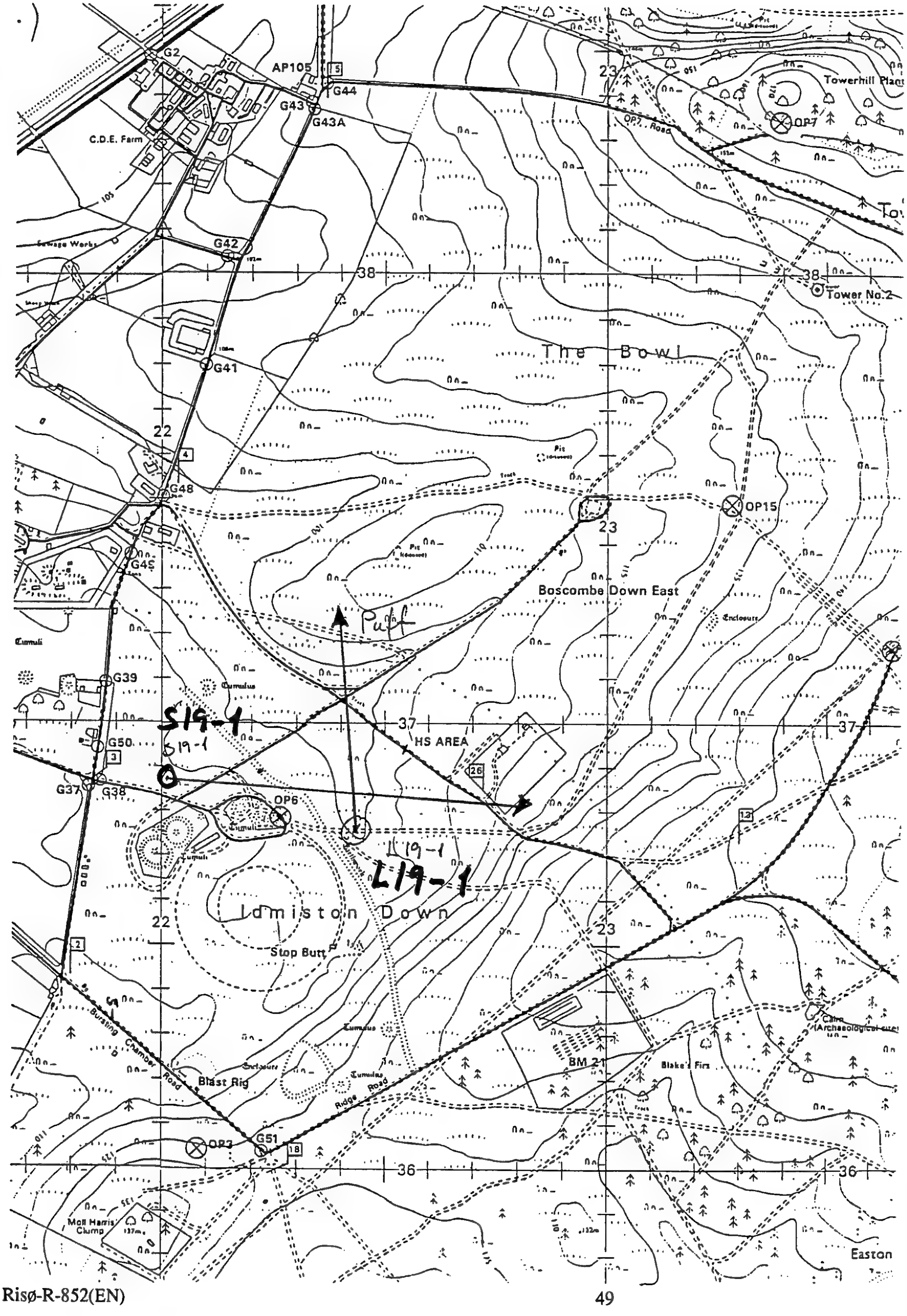


G2
AP105
5
G44
G43
G43A
C.D.E. Farm
23
Towerhill Plantation
OP7
OP7 Road
Tower
G42
38
Tower No.2
The Bowl
G41
22
4
G48
OP15
23
G45
Boscombe Down East
Enclosure
G45
OP14
G39
Cout
37
HS AREA
G50
3
26
G37
G38
OP6
L18-1
L18-1
Idmiston Down
13
22
23
2
Stop Butt
S18-1
Cairn (Archaeological site)
Tumulus
S18-1
BM 21
Bursting Chamber Road
Blast Rig
Enclosure
Tumulus
Ridge Road
Blake's Firs
OP3
G51
18
36
36
Moll Harris' Clump
Easton Down

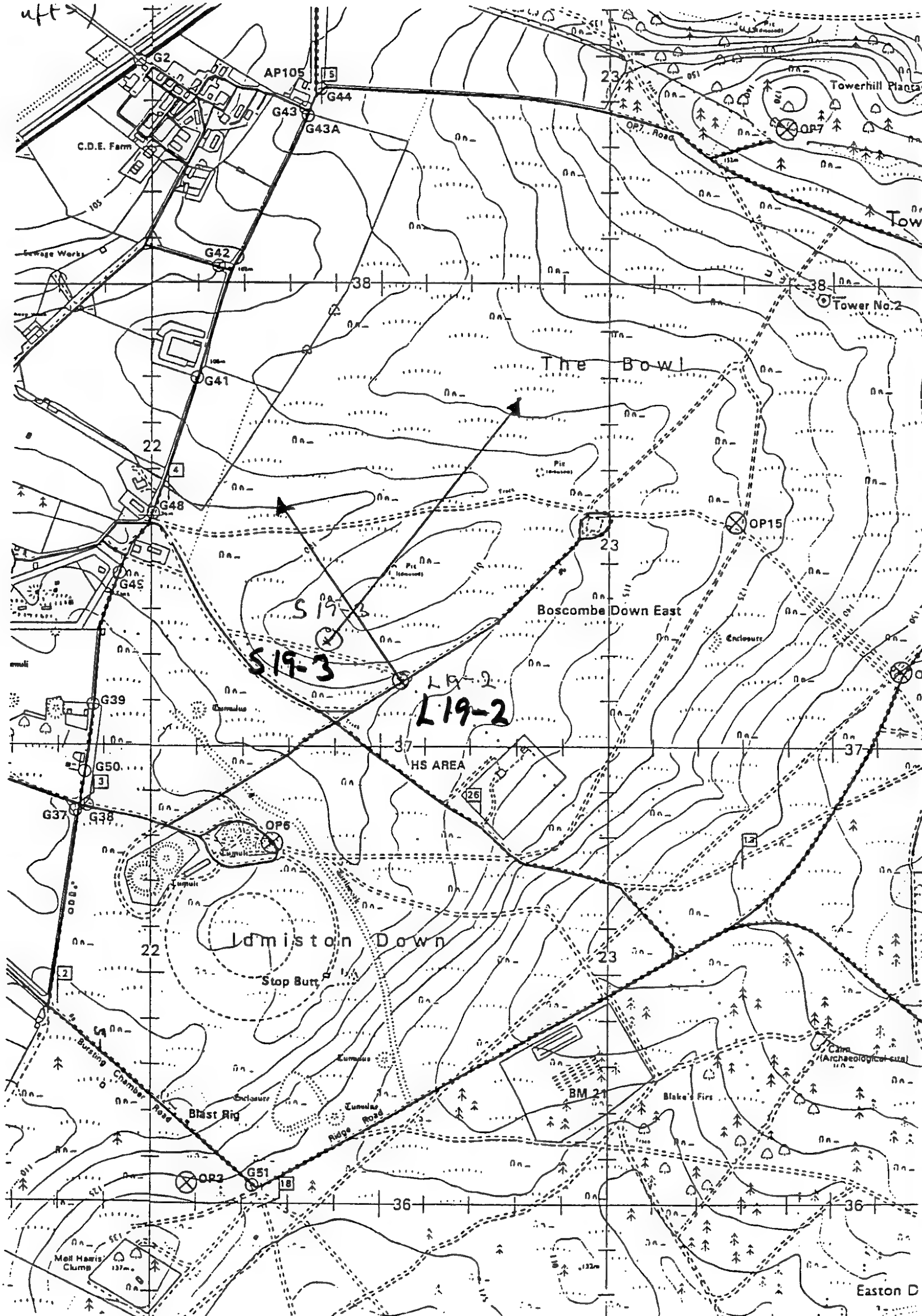

G2
AP105
G44
G43
G43A
C.D.E. Farm
Towerhill Plantation
OP7
Tower Hi
G42
38
Tower No.2
The Bowl
G41
22
G48
OP15
23
G45
Boscombe Down East
puff
Enclosure
OP14
G39
Tumulus
37
HS AREA
G50
G38
OP6
Tumuli
L19-1a
L19-1a
Idmiston Down
S19-1a
Stop Butt
Cairn
(Archaeological site)
Bursting Chamber Road
Tumulus
BM 21
Blake's Firs
Blast Rig
Ridge Road
OP3
G51
36
Moll Harris Clump
Easton Down

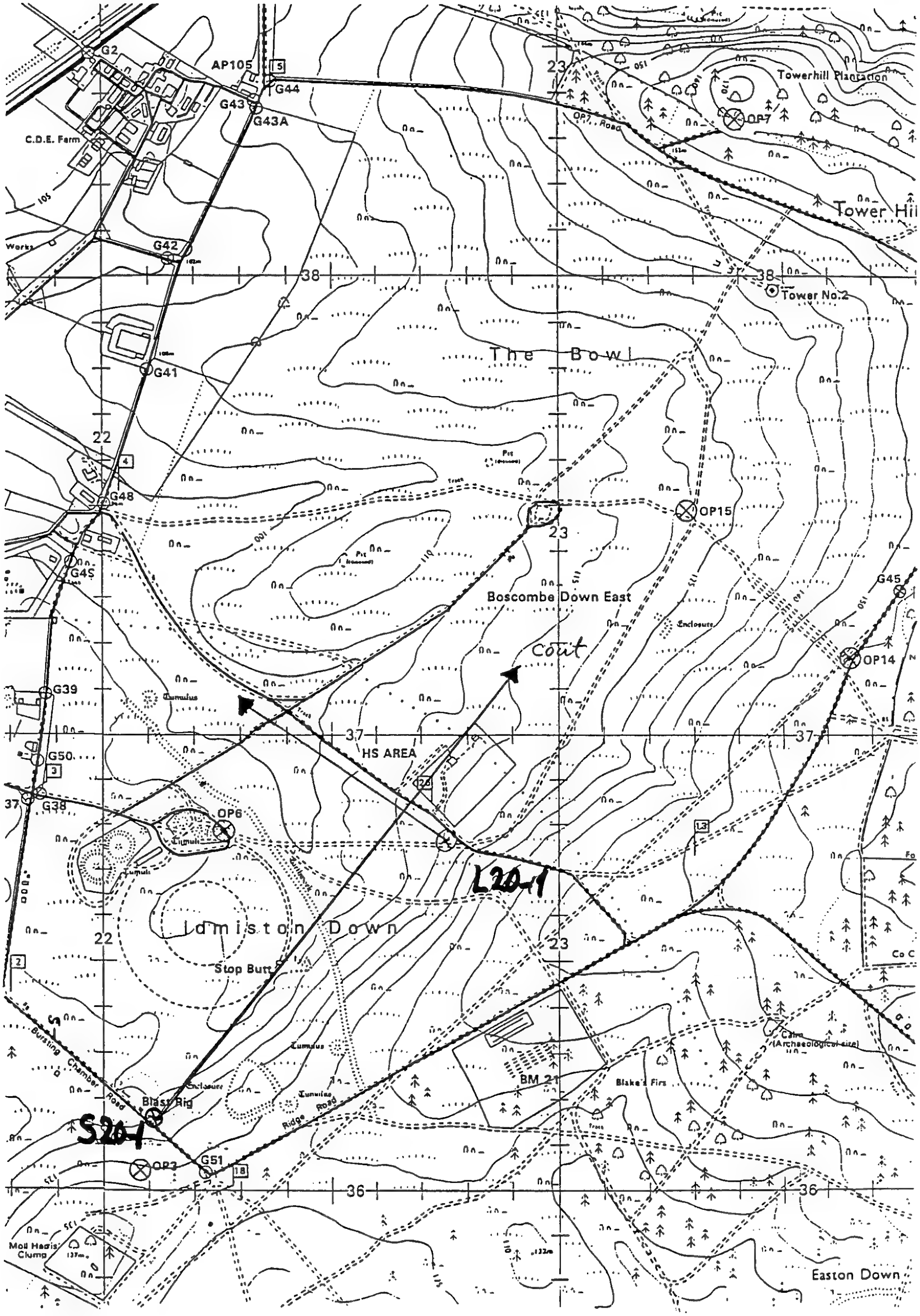


G2
AP105
G44
G43
G43A
C.D.E. Farm
Towerhill Plantation
OP7
Road
Sewage Works
G42
38
Tower No.2
The Bowl
G41
22
G48
OP15
23
G45
Boscombe Down East
Enclosure
Tumulus
G39
Camp
37
HS AREA
S19-1
G50
G37
G38
OP6
Tumuli
L19-1
Idmiston Down
Stop Butt
Cairn (Archaeological site)
Tumulus
BM 21
Blake's Firs
Bursting Chamber Road
Blast Rig
Enclosure
Tumulus
Ridge Road
OP3
G51
36
Moll Harris's Clump
Easton Down

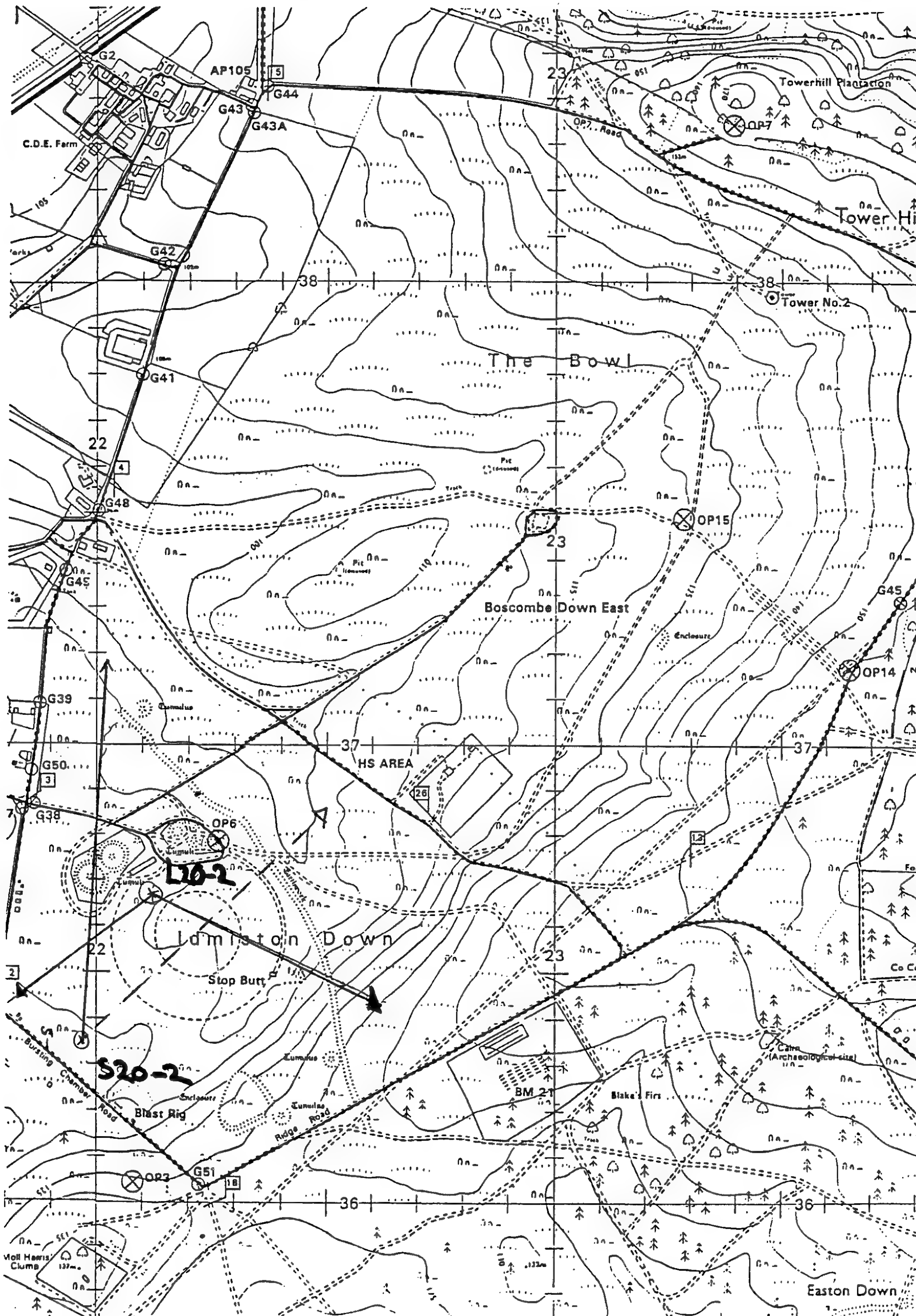


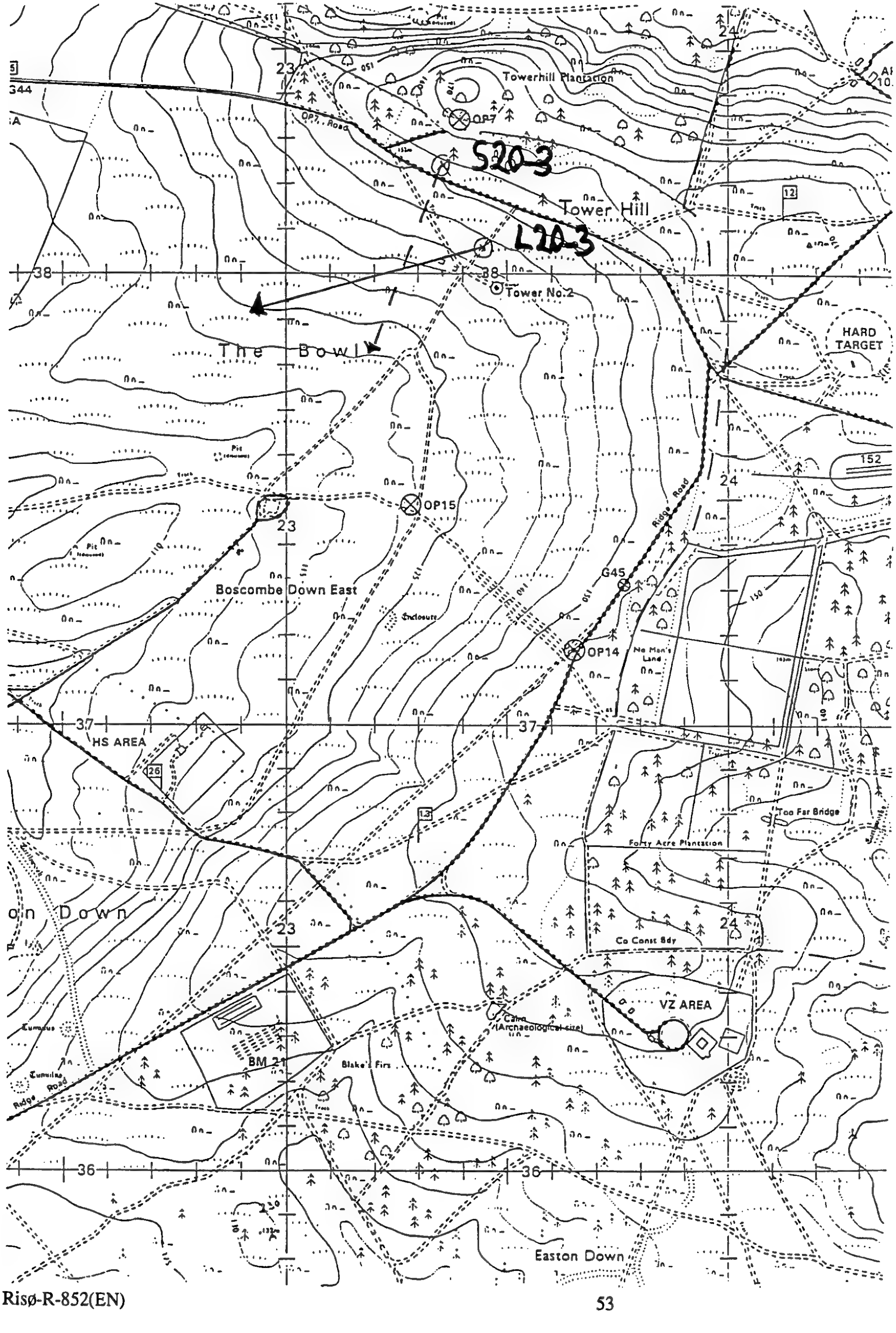
C.D.E. Farm
G2
AP105
G44
G43
G43A
G42
G41
G48
G45
G39
G50
G37
G38
OP6
OP7
OP15
OP3
G51
Towerhill Plant
Tower No.2
The Bowl
Boscombe Down East
HS AREA
Idmiston Down
Stop Butt
BM 21
Blake's Firs
Bursting Chamber Road
Blast Rig
Ridge Road
Moll Harris' Clump
Easton
Cairn (Archaeological site)
Enclosure
Tumuli
Cumulus
Sewage Works
Puff
S19-1
L19-1
22
23
36
37
38


uft
G2
AP105
15
G44
G43
G43A
C.D.E. Farm
Towerhill Plantat
OP7
OP7 Road
Sewage Works
G42
38
Tower No.2
The Bowl
G41
22
4
G48
OP15
23
G45
S19-3
Boscombe Down East
S19-3
L19-2
L19-2
G39
37
HS AREA
G50
3
26
G37
G38
OP6
Idmiston Down
22
23
Stop Butt
2
Cairn (Archaeological site)
BM 21
Blake's Firs
Bursting Chamber Road
Blast Rig
Ridge Road
G51
OP2
18
36
36
Moll Harris' Clump
Easton D

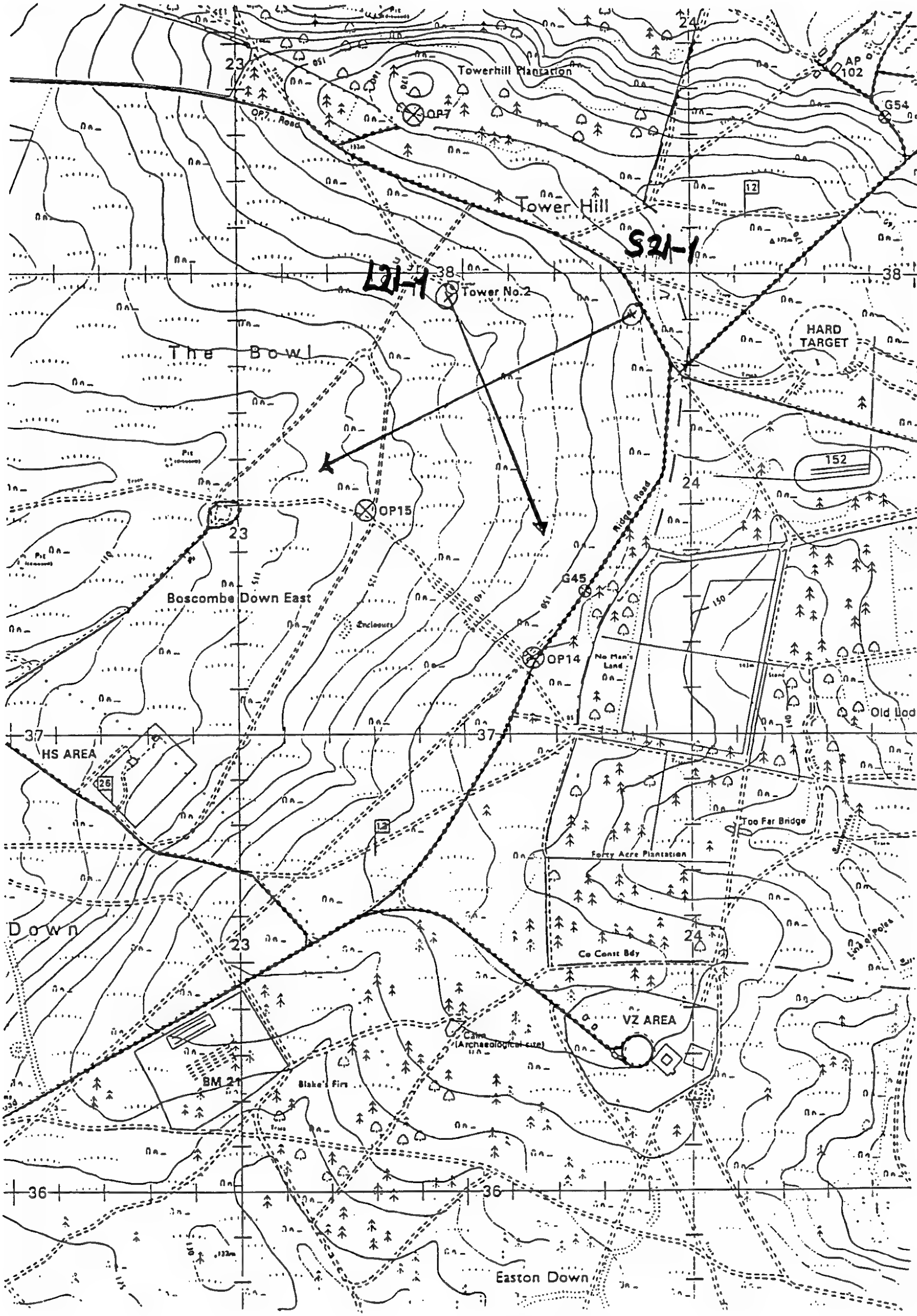


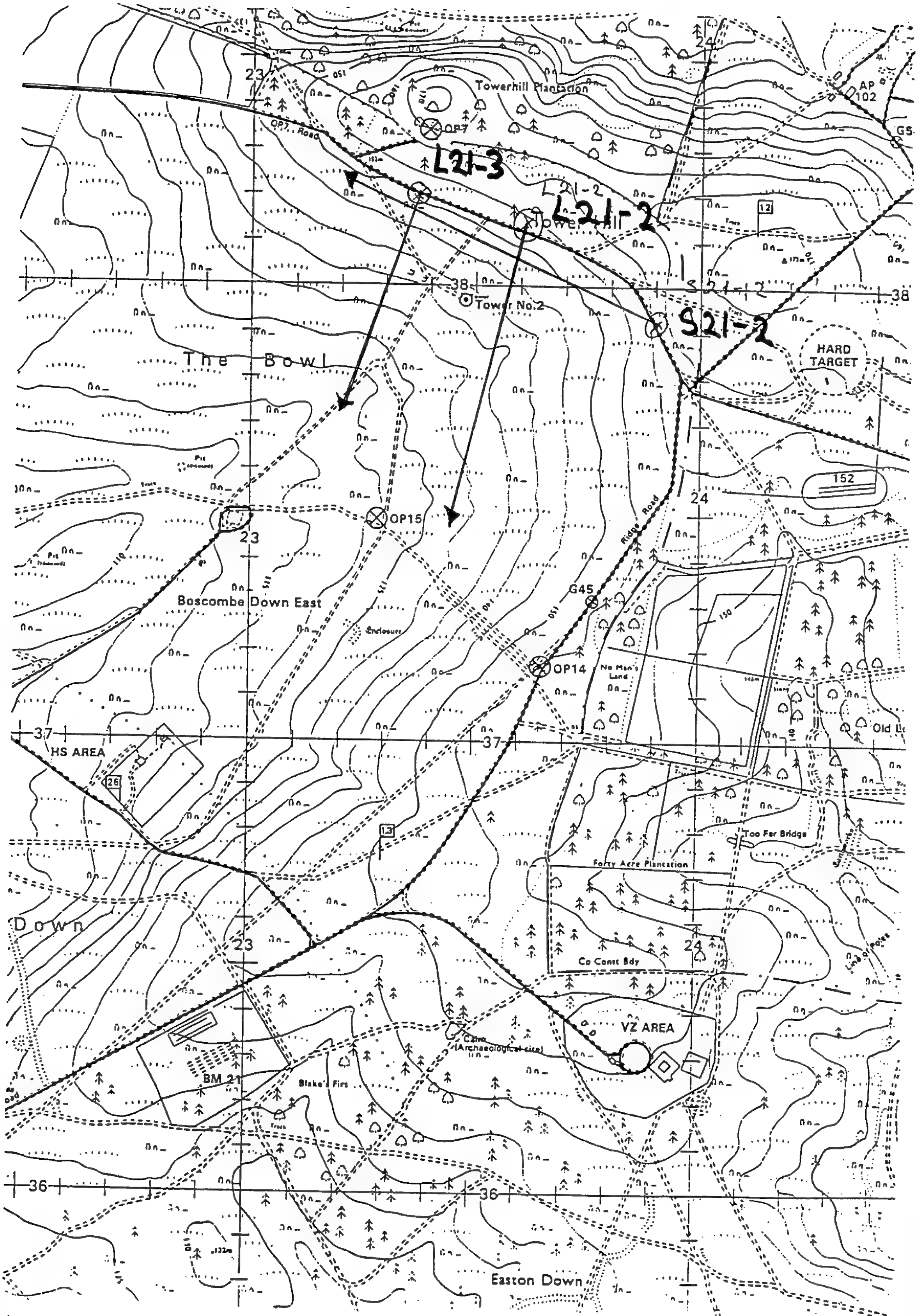
G2
AP105
G44
G43
G43A
C.D.E. Farm
Towerhill Plantation
OP7
Tower Hill
Works
G42
38
Tower No.2
The Bowl
G41
22
G48
OP15
23
G45
Boscombe Down East
Enclosure
Cout
OP14
G39
Tumulus
37
HS AREA
G50
G38
OP6
Tumuli
L20-1
Idmiston Down
Stop Butt
Bursting Chamber Road
Tumulus
Cairn (Archaeological site)
BM 21
Blake's Firs
Blast Rig
S20-1
Ridge Road
G51
OP3
36
Moll Harris' Clump
Easton Down


G2
AP105
G44
G43
G43A
C.D.E. Farm
G42
G41
G48
G49
G39
G50
G38
OP7
Towerhill Plantation
Tower Hi
Tower No.2
The Bowl
OP15
Boscombe Down East
Enclosure
G45
OP14
HS AREA
OP6
L20-2
Idmiston Down
Stop Butt
S20-2
Bursting Chamber Road
Blast Rig
Ridge Road
G51
OP3
BM 21
Blake's Firs
Cairn (Archaeological site)
Moll Harris' Clump
Easton Down
22
23
36
37
38

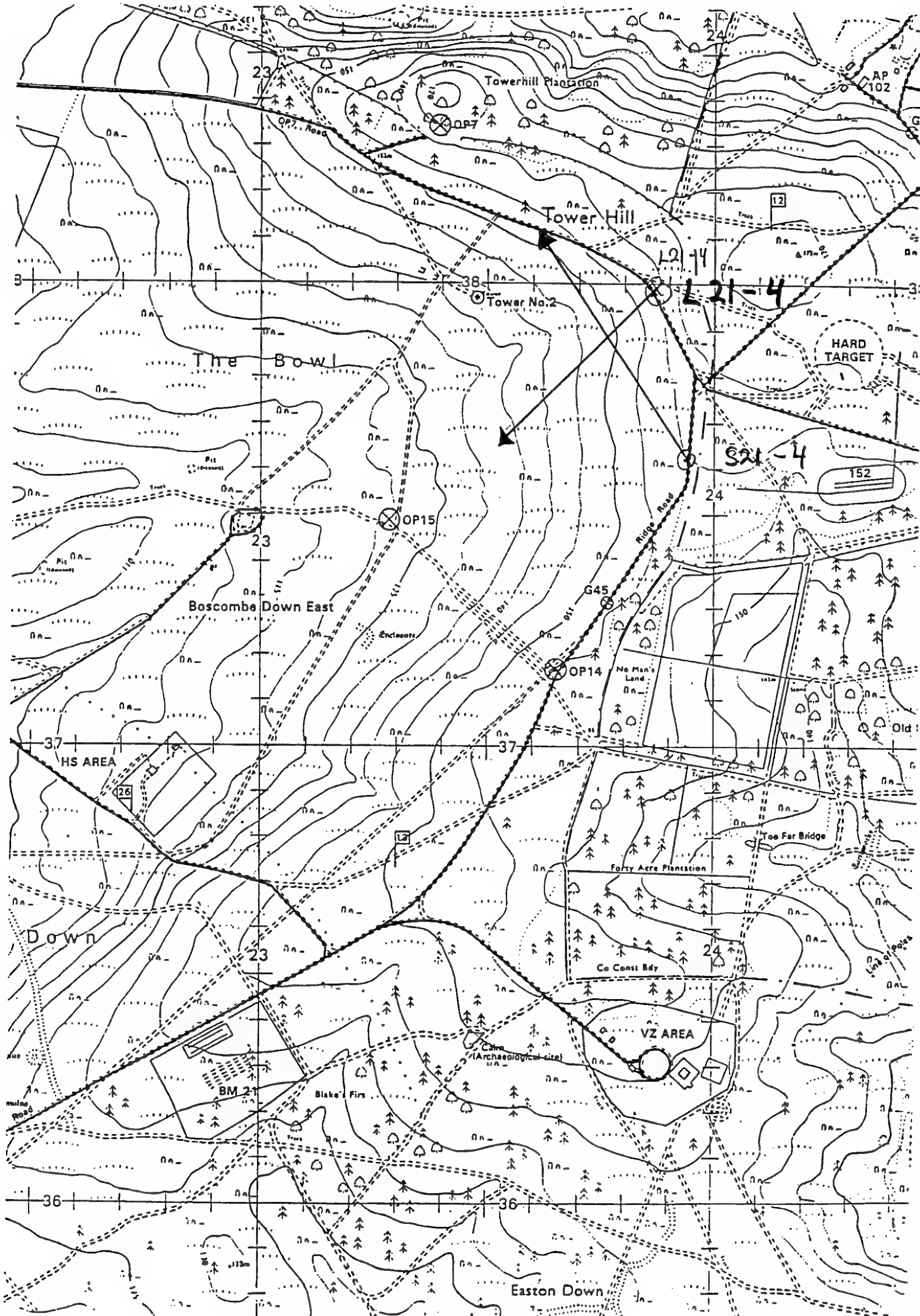


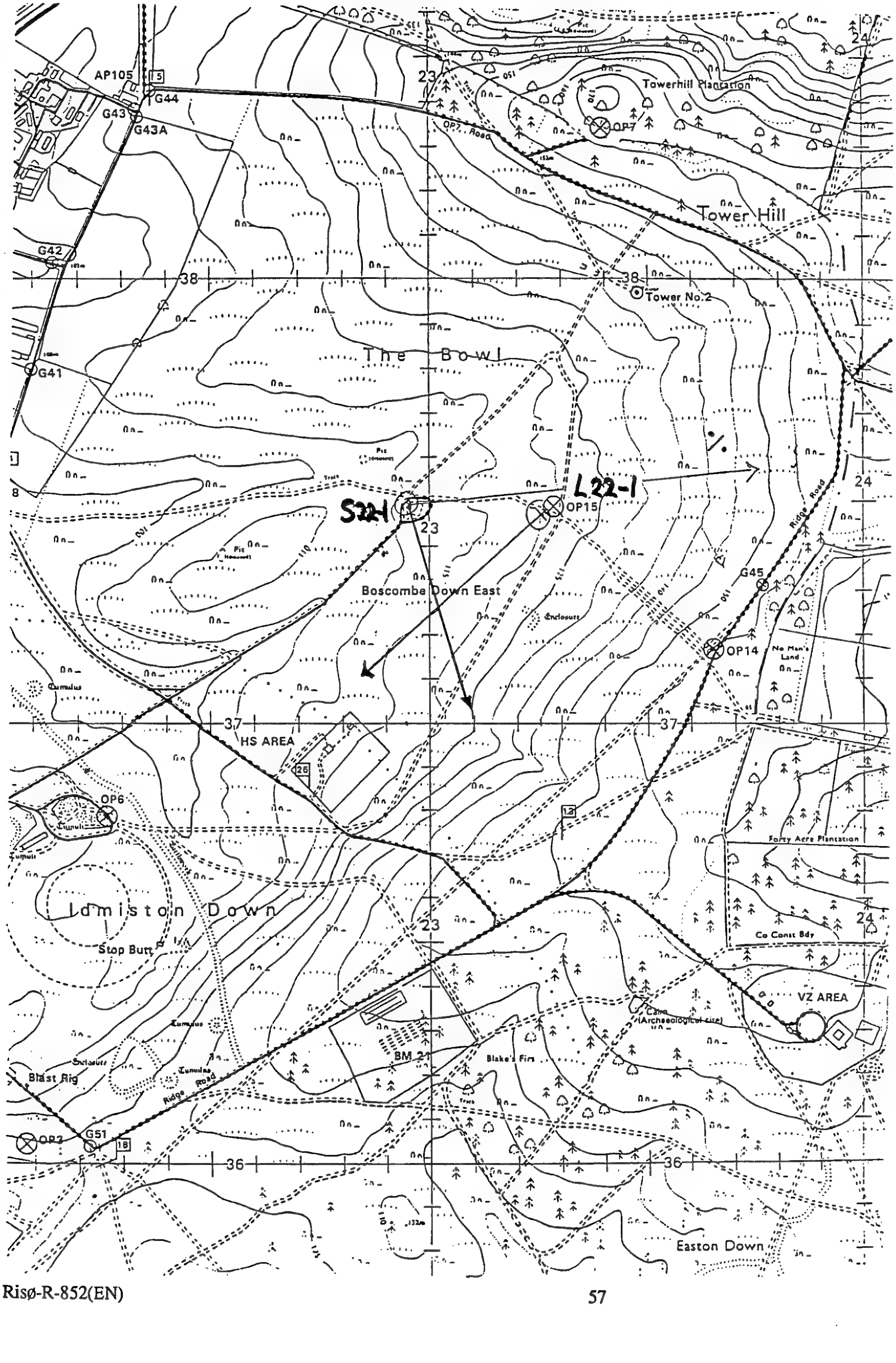
Towerhill Plantation
OP7
S20-3
Tower Hill
L20-3
Tower No.2
HARD TARGET
The Bowl
OP15
Boscombe Down East
Enclosure
G45
OP14
No Man's Land
Ridge Road
HS AREA
Too Far Bridge
Forty Acre Plantation
Co Const Bdy
VZ AREA
Cairn (Archaeological site)
BM 21
Blake's Firs
Easton Down


Towerhill Plantation
OP7
AP 102
G54
Tower Hill
S21-1
L21-1
Tower No.2
HARD TARGET
The Bowl
152
OP15
Boscombe Down East
G45
Ridge Road
Enclosure
OP14
No Man's Land
Old Lod
HS AREA
26
12
13
Too Far Bridge
Forty Acre Plantation
Down
Co Const Bdy
VZ AREA
Cairn (Archaeological site)
BM 21
Blake's Firs
Easton Down
23
24
36
37
38

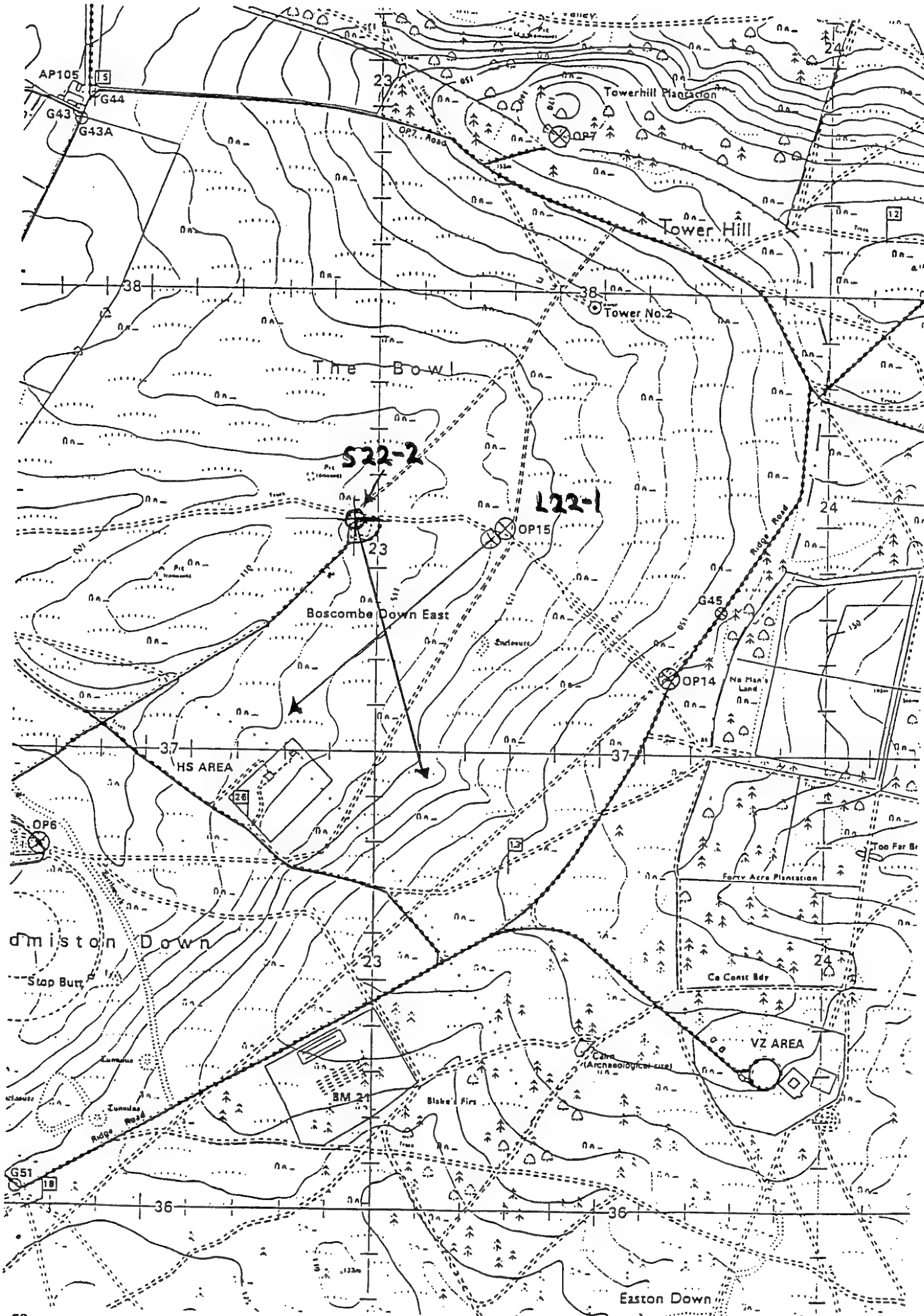


Towerhill Plantation
OP7
Road
L21-3
L21-2
Tower Hill
38
Tower No.2
S21-2
HARD TARGET
AP 102
G5
The Bowl
OP15
23
24
152
Boscombe Down East
G45
Ridge Road
OP14
No Man's Land
Enclosure
37
HS AREA
26
13
Old
Too Far Bridge
Forty Acre Plantation
Down
Co Const Bdy
VZ AREA
Cairn (Archaeological site)
BM 21
Blake's Firs
36
Easton Down

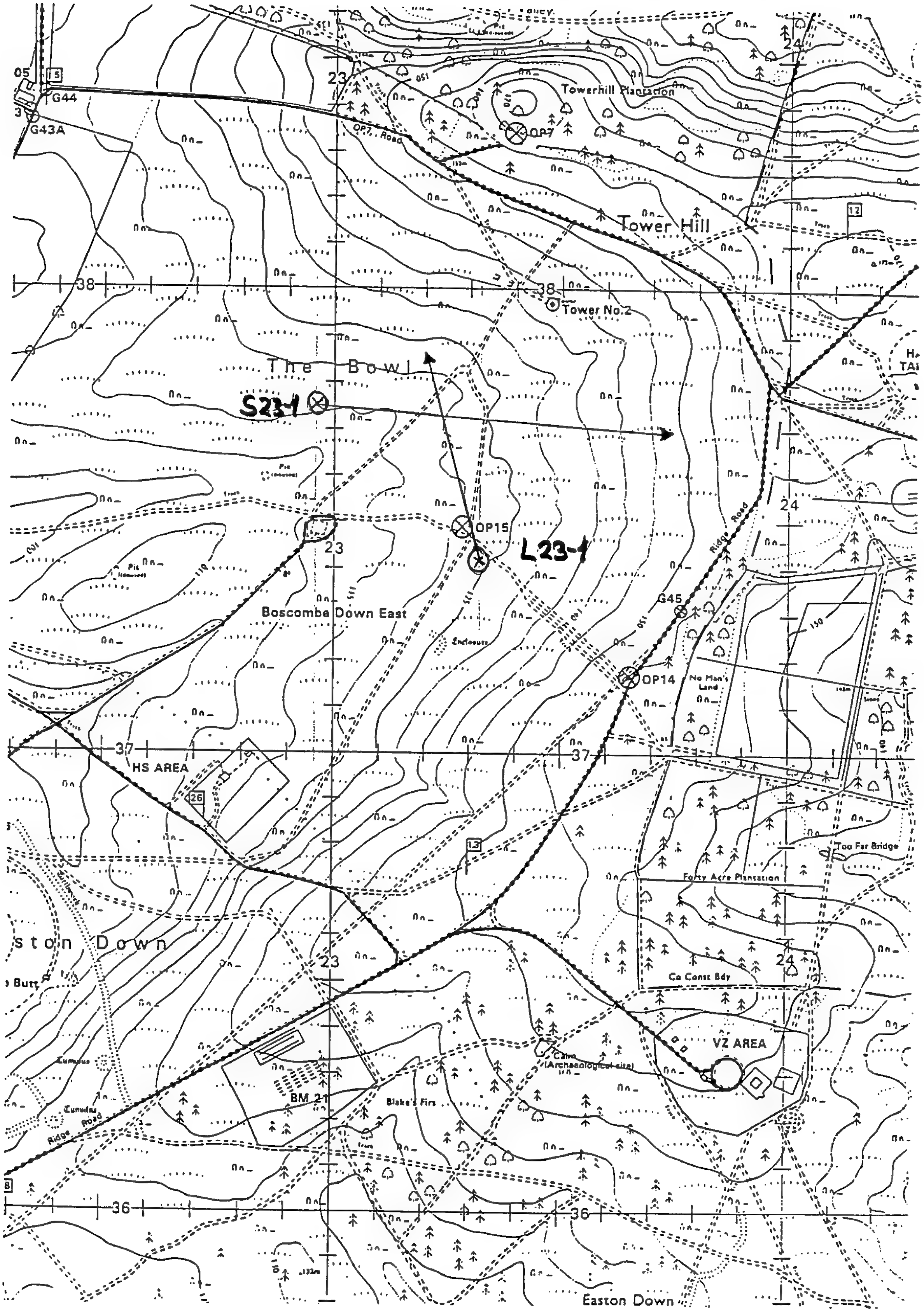

Towerhill Plantation
OP7
AP 102
Tower Hill
L21-4
Tower No.2
HARD TARGET
The Bowl
S21-4
152
OP15
Ridge Road
Boscombe Down East
G45
Enclosure
OP14
No Man's Land
HS AREA
26
Too Far Bridge
Forty Acre Plantation
Down
Co Const Bdy
VZ AREA
Cairn (Archaeological site)
BM 21
Blake's Firs
Easton Down
Line of Poles



AP105
G44
G43
G43A
G42
G41
Towerhill Plantation
OP7
Road
Tower Hill
Tower No.2
The Bowl
L22-1
S22-1
OP15
Ridge Road
G45
Boscombe Down East
Enclosure
OP14
No Man's Land
Cumulus
HS AREA
OP6
Tumuli
Forty Acre Plantation
Idmiston Down
Stop Butt
Co Const Bdy
VZ AREA
Cairn (Archaeological site)
BM 21
Blake's Firs
Tumulus
Blast Rig
Ridge Road
OP3
G51
Easton Down
38
37
36
23
24



S22-2
L22-1
AP105
G44
G43
G43A
OP7
Towerhill Plantation
Tower Hill
Tower No.2
The Bowl
OP15
Boscombe Down East
G45
OP14
No Man's Land
HS AREA
OP6
Forty Acre Plantation
Stop Butt
Ca Const Bdy
VZ AREA
Cairn (Archaeological site)
BM 21
Blake's Firs
Ridge Road
G51
Easton Down
Enclosure
Too Far Br



Towerhill Plantation
OP7
G44
G43A
Tower Hill
38
Tower No.2
The Bowl
S23-1
OP15
L23-1
23
24
Boscombe Down East
G45
OP14
Ridge Road
No Man's Land
37
HS AREA
Too Far Bridge
Forty Acre Plantation
ston Down
Co Const Bdy
VZ AREA
Cairn (Archaeological site)
BM 21
Blake's Firs
36
Easton Down

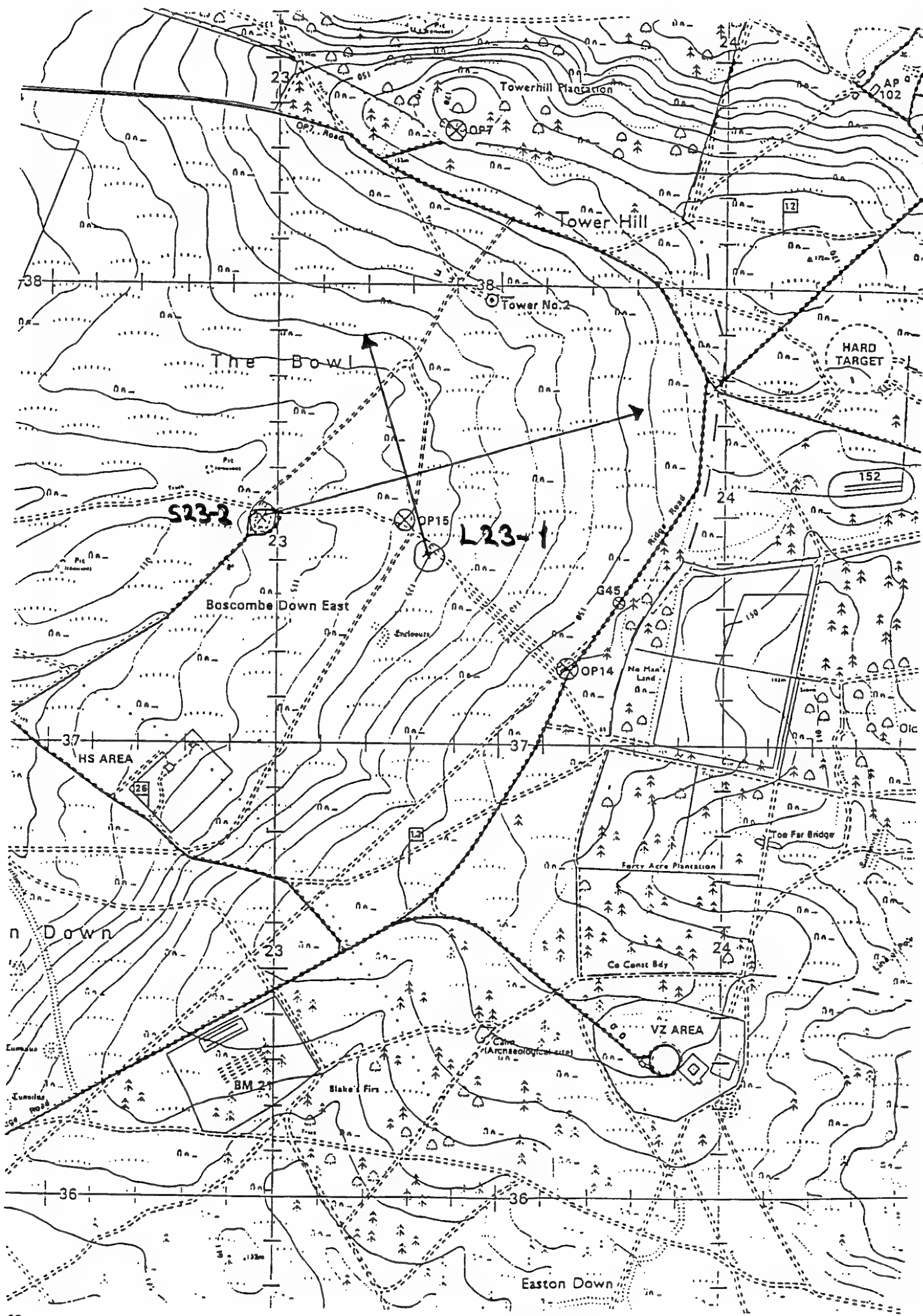
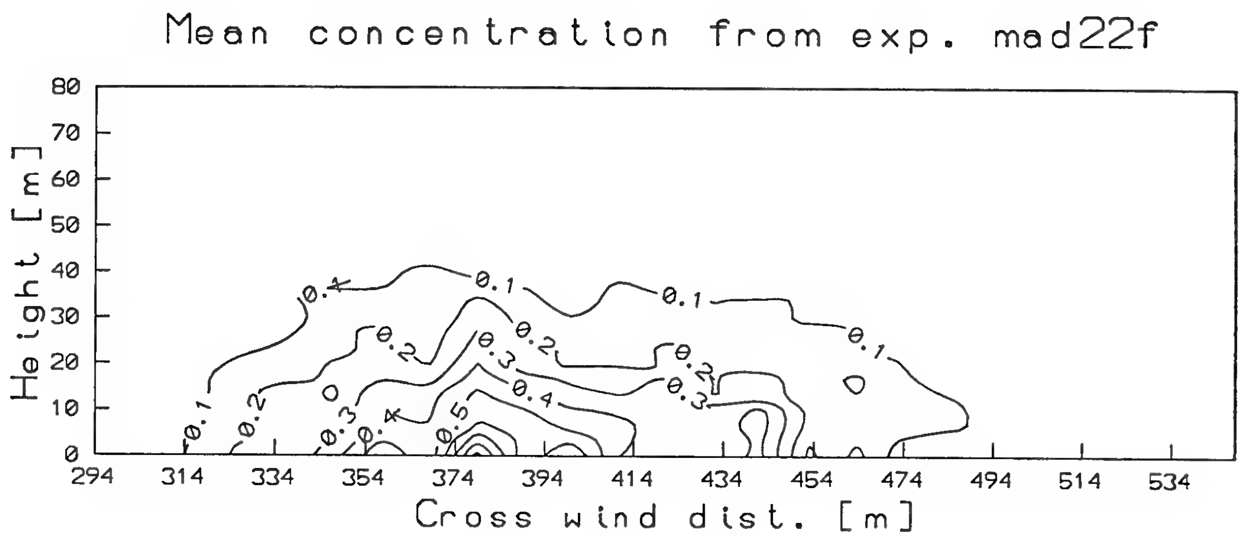

Towerhill Plantation
OP7
AP 102
Tower Hill
Tower No.2
HARD TARGET
The Bowl
152
S23-2
OP15
L23-1
Ridge Road
G45
Boscombe Down East
OP14
No Man's Land
HS AREA
Toe Far Bridge
Forty Acre Plantation
Co Const Bdy
VZ AREA
BM 21
Blake's Firs
Easton Down

Figure III.1



Mean concentration from exp. mad22f
Height [m]
Cross wind dist. [m]

Figure III.2a

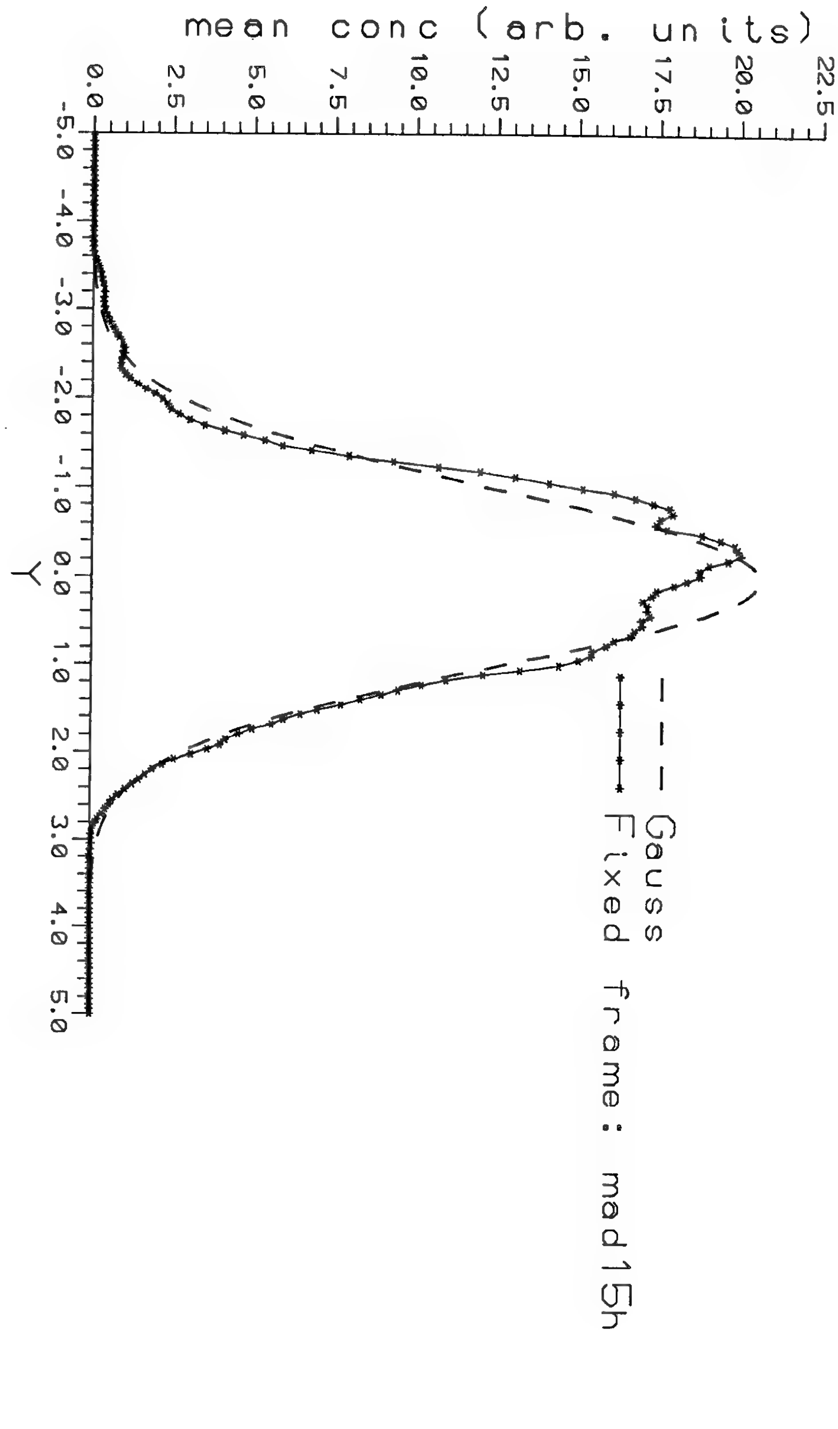


Figure III.2b

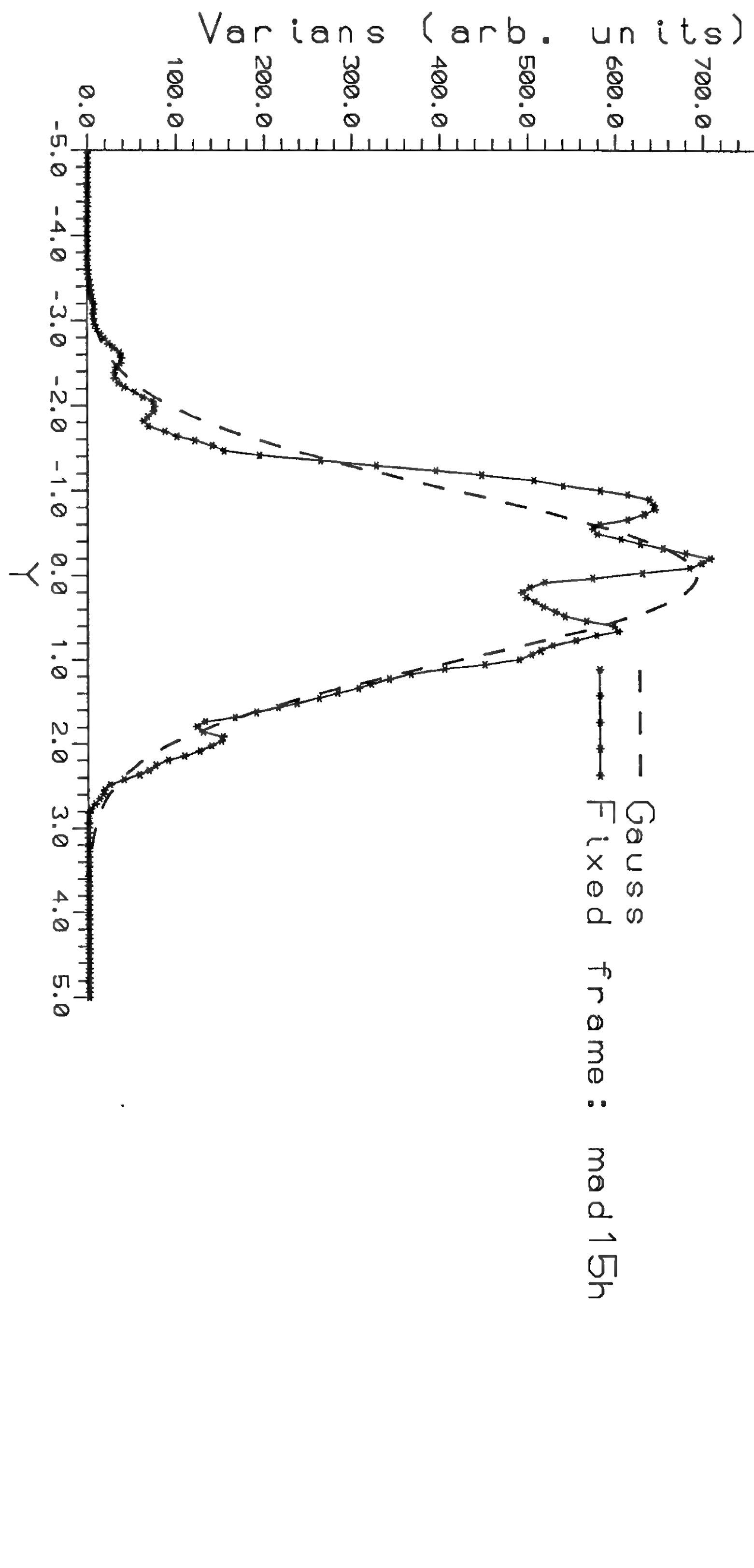


Figure III.2c

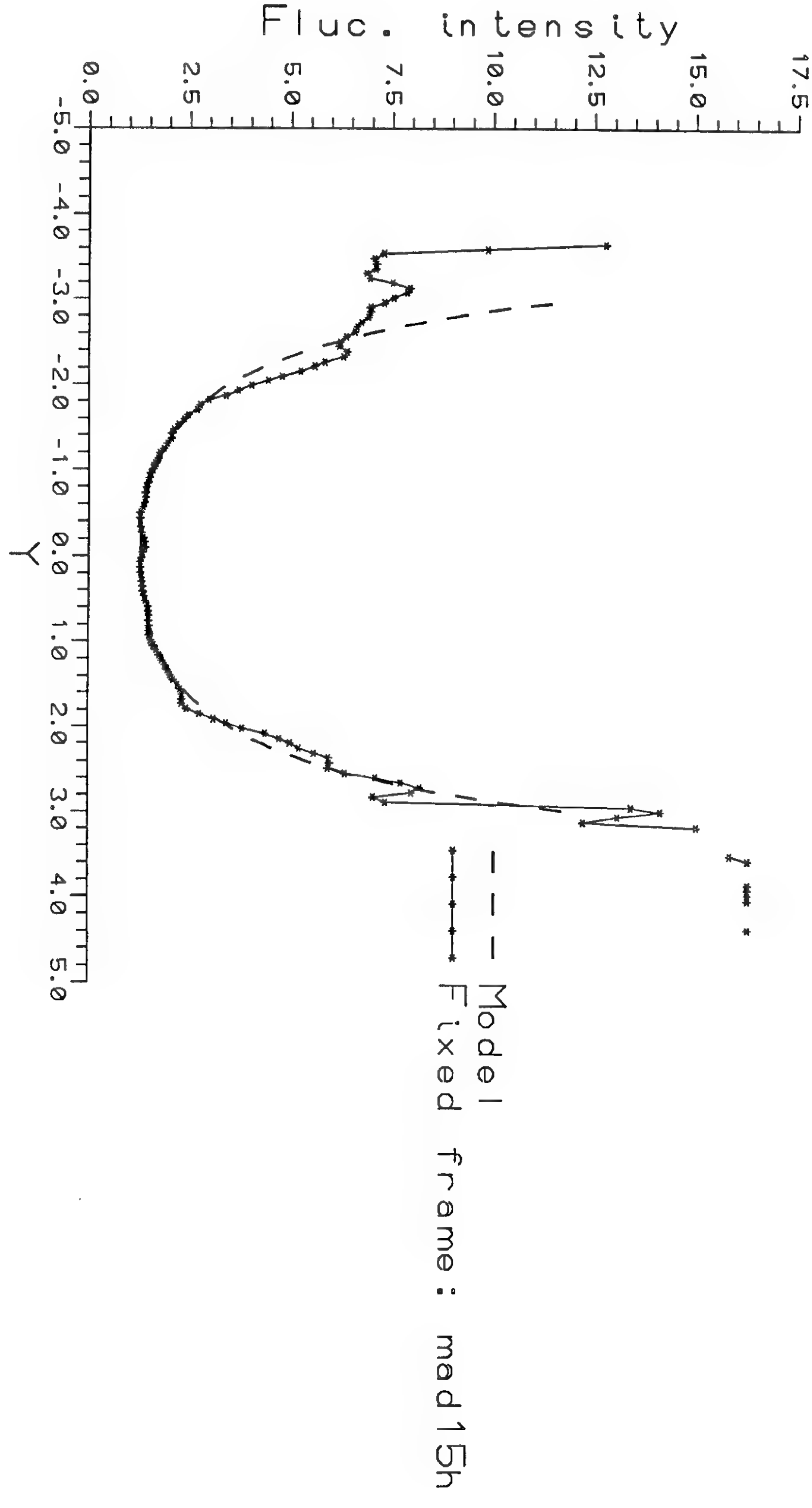


Figure III.2d

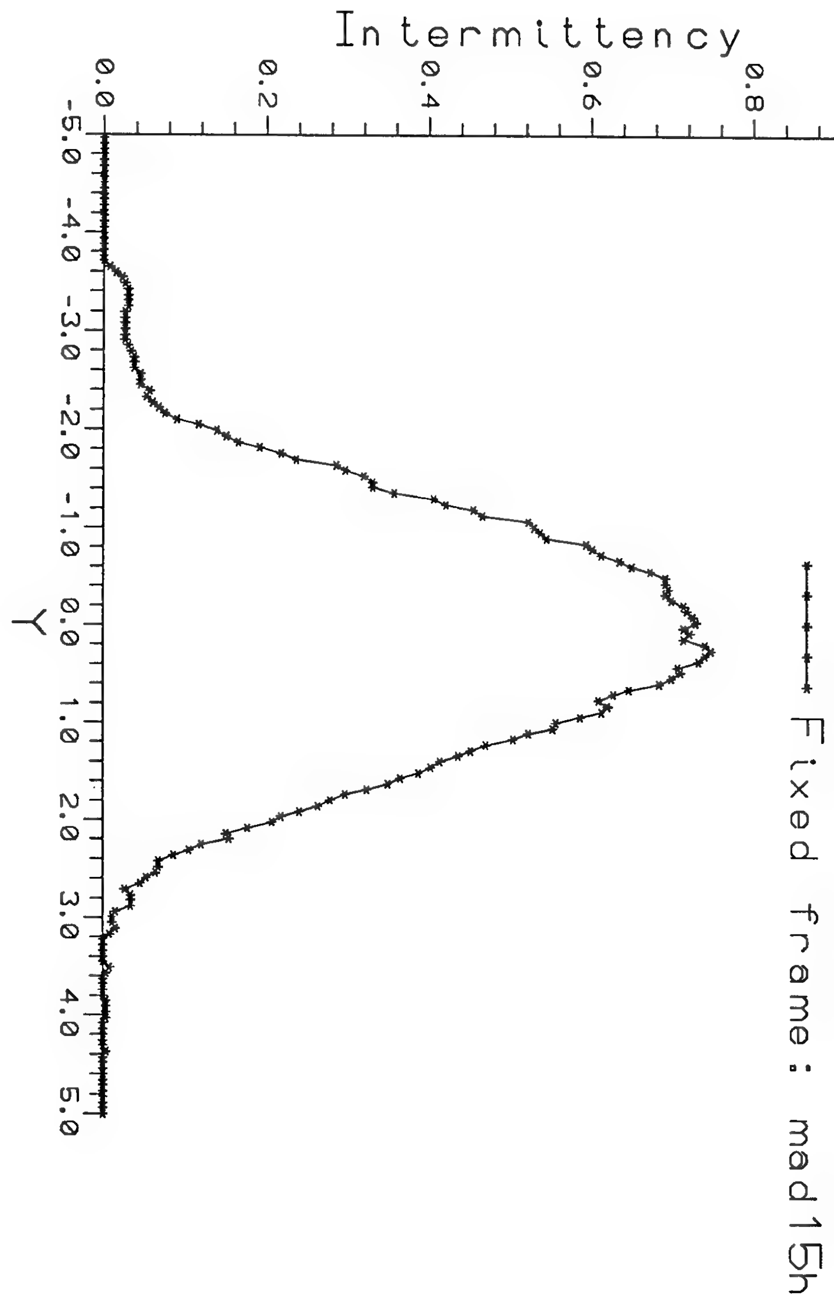


Figure III.3a

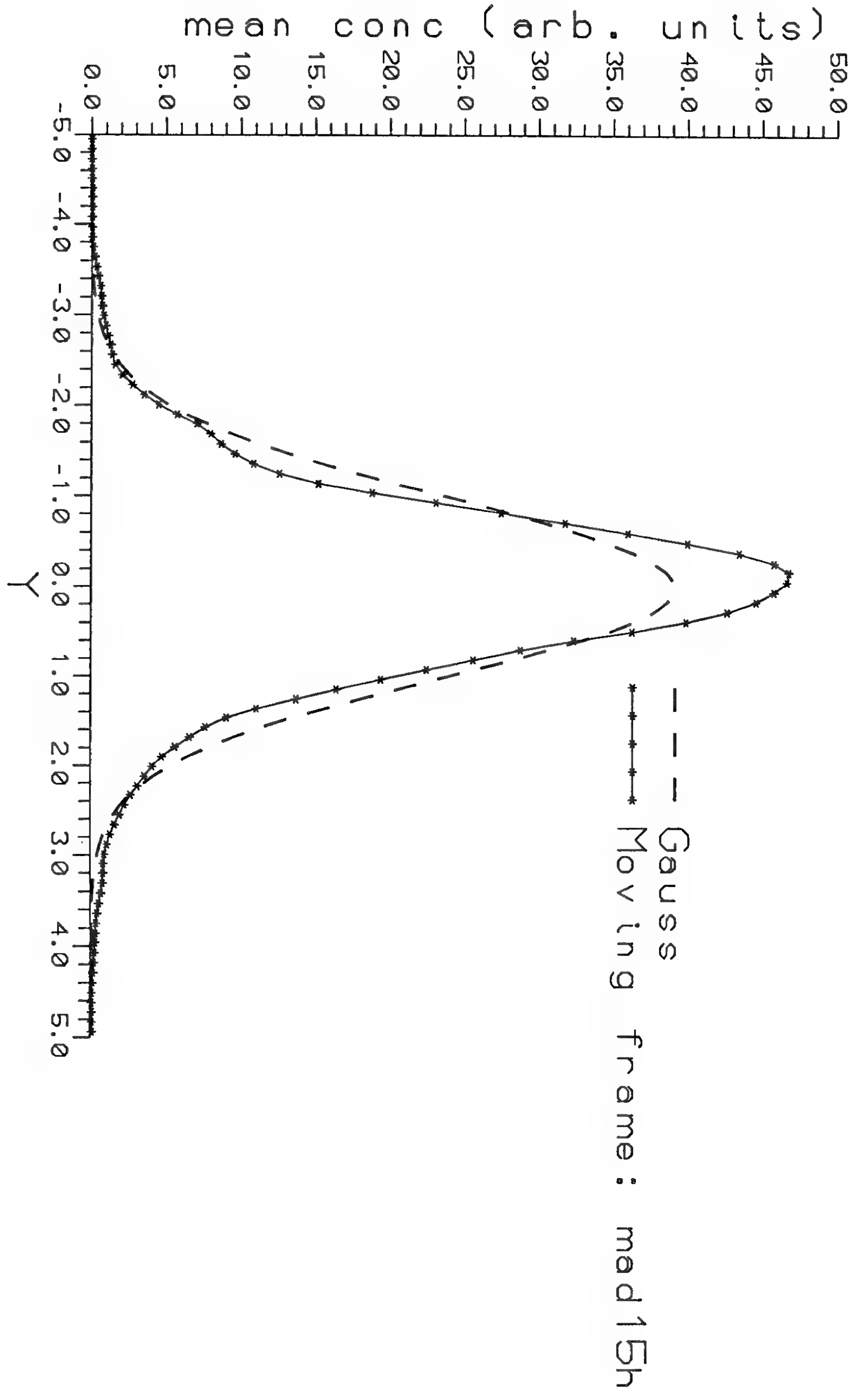
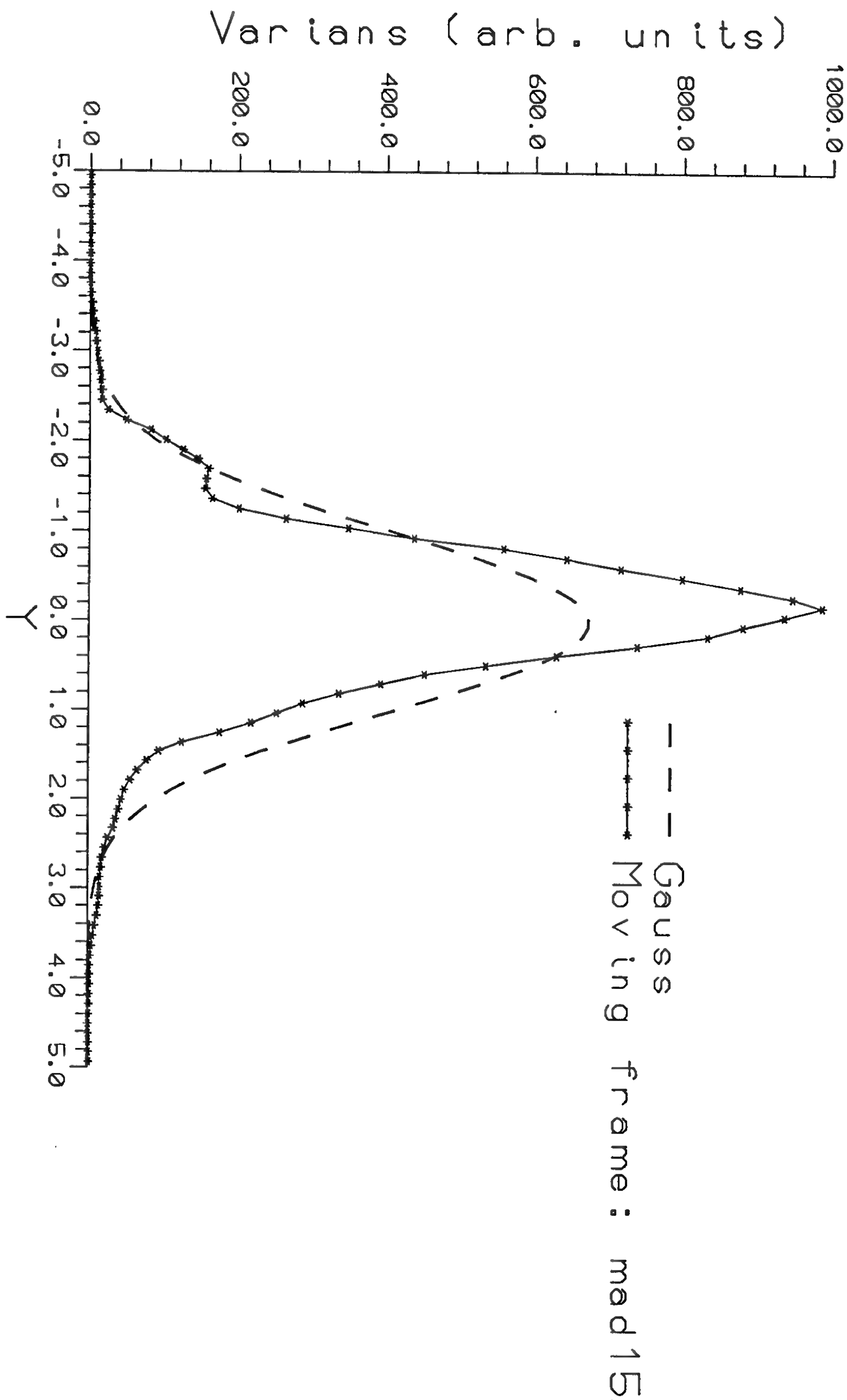


Figure III.3b



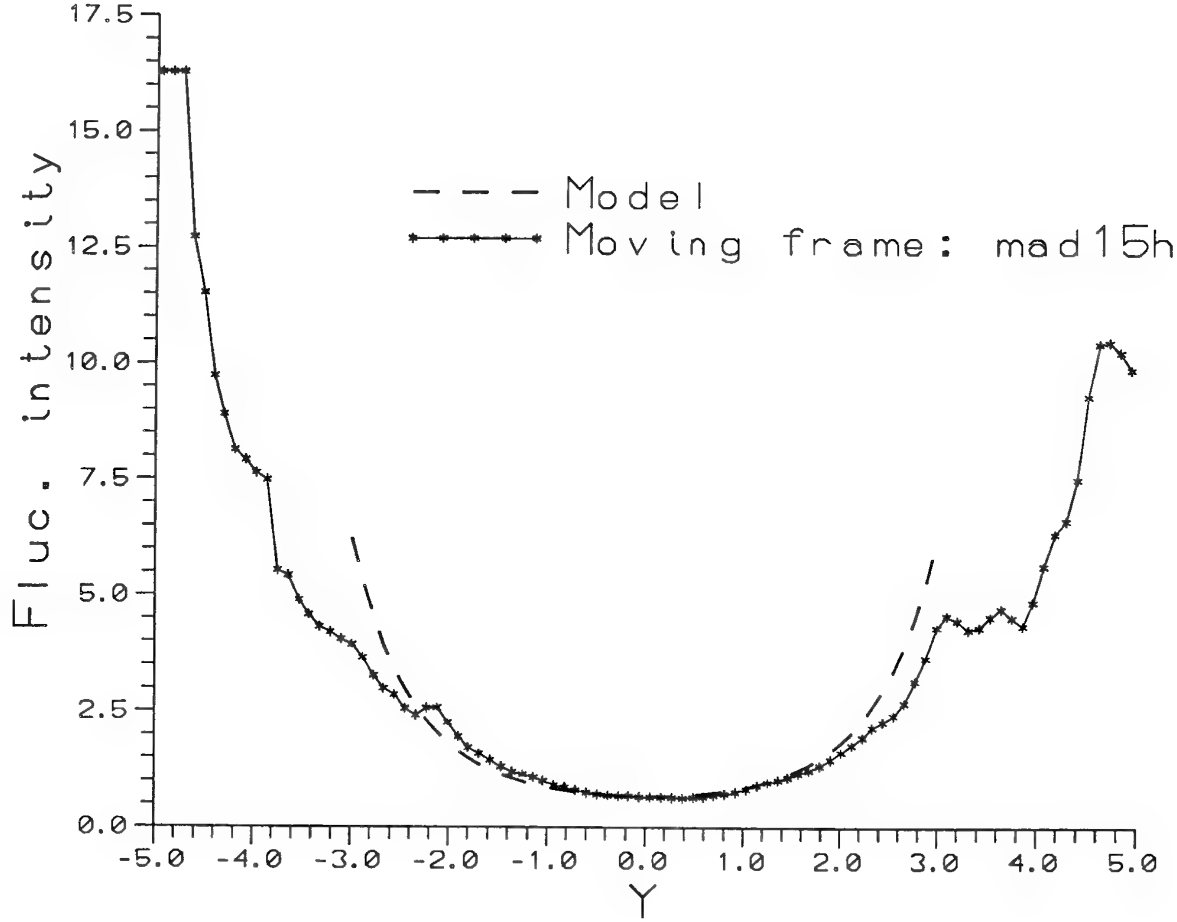


Figure III.3c

Figure III.3d

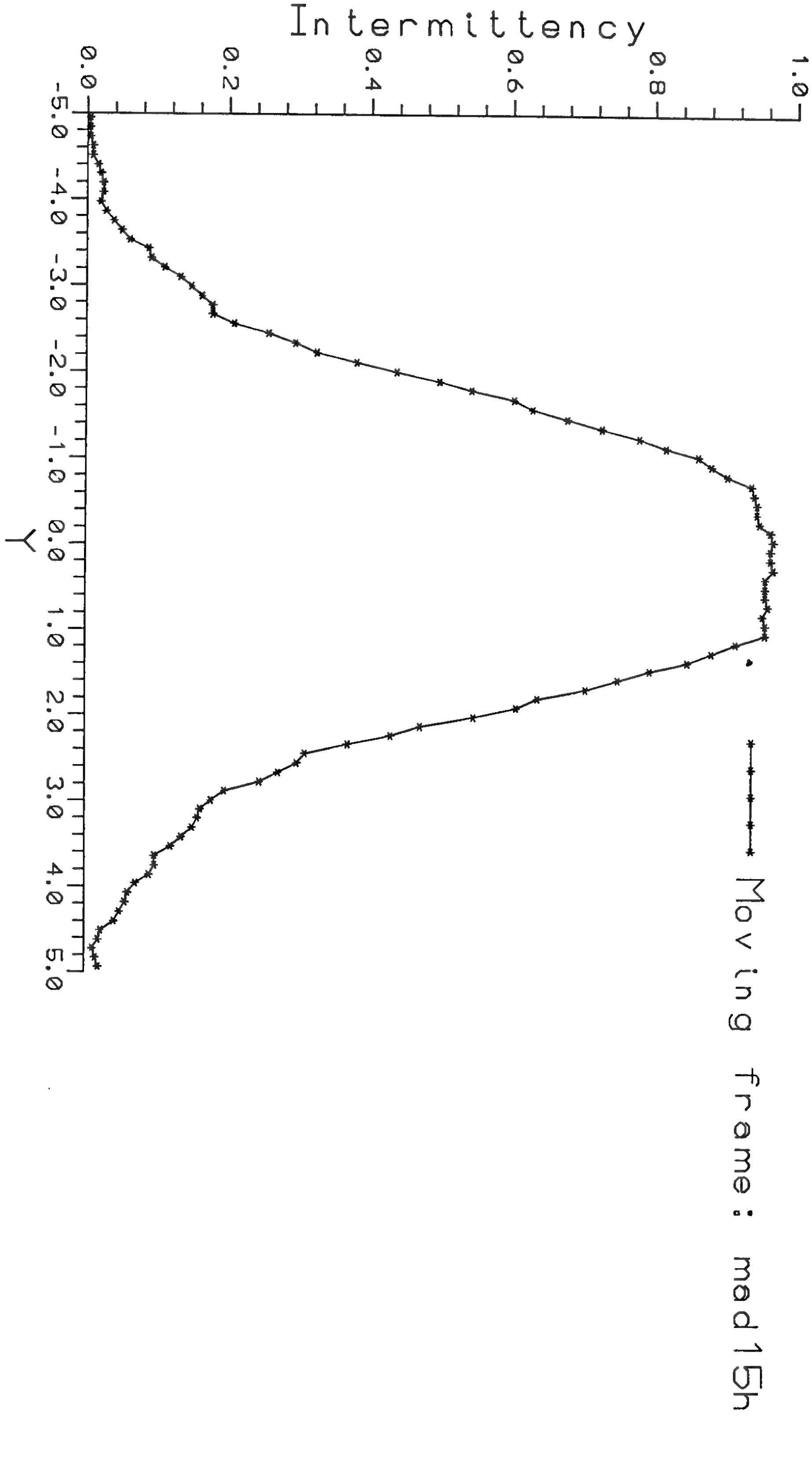


Figure IV.1. Lincom Flow Modelling

Porton
September 17, 1992
Release Time: 11:10 - 16:10
Hourly fitted Windfields

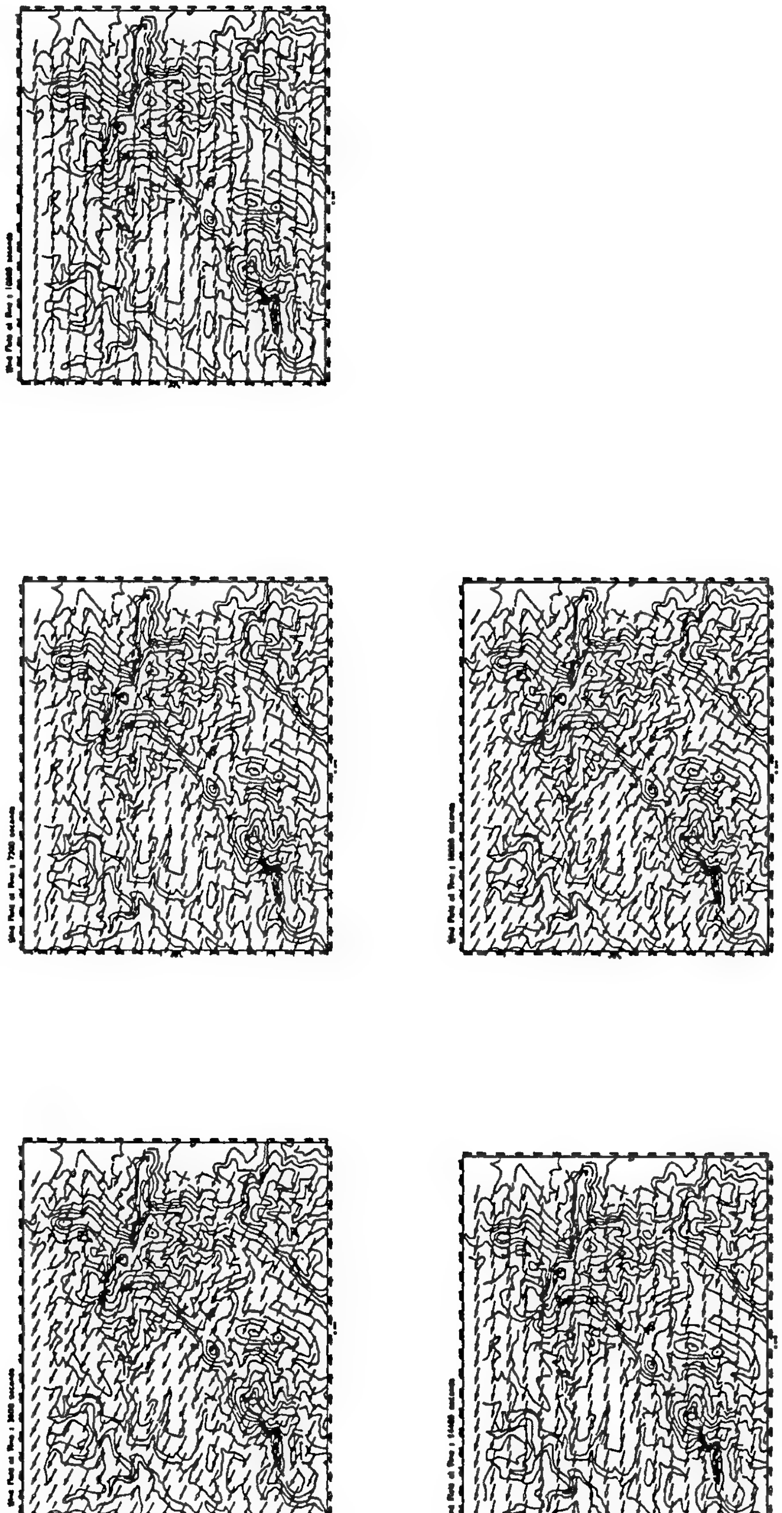


Figure IV.2. Rimpoff Sim

Porton

September 17, 1992

Release Time: 11:10 - 16:10

10 minute series of puffs

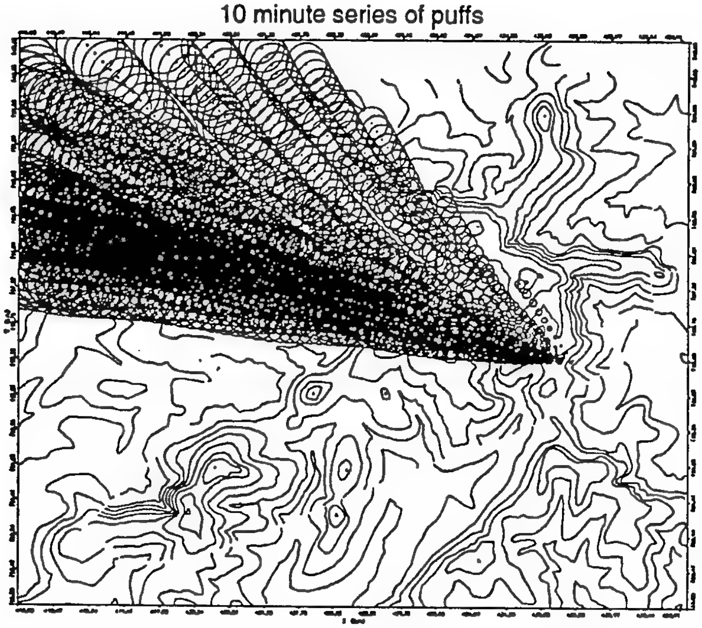


Figure IV.2

5 hour integrated concentrations

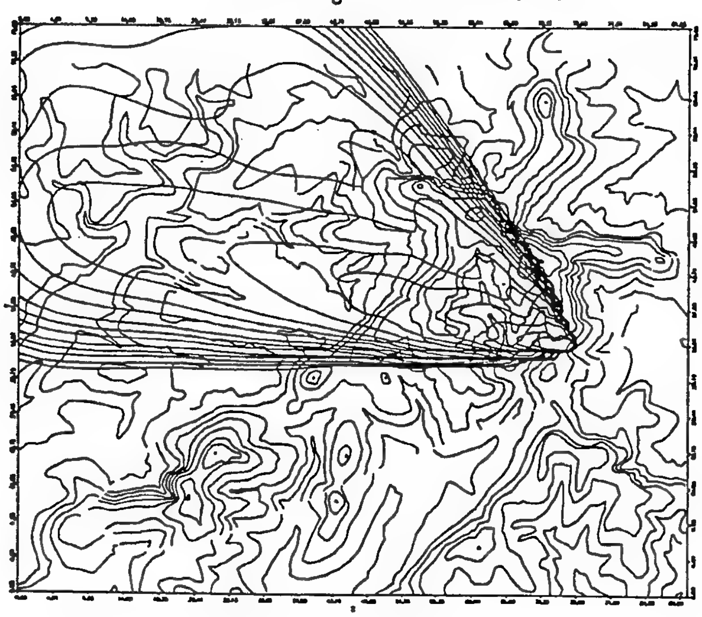
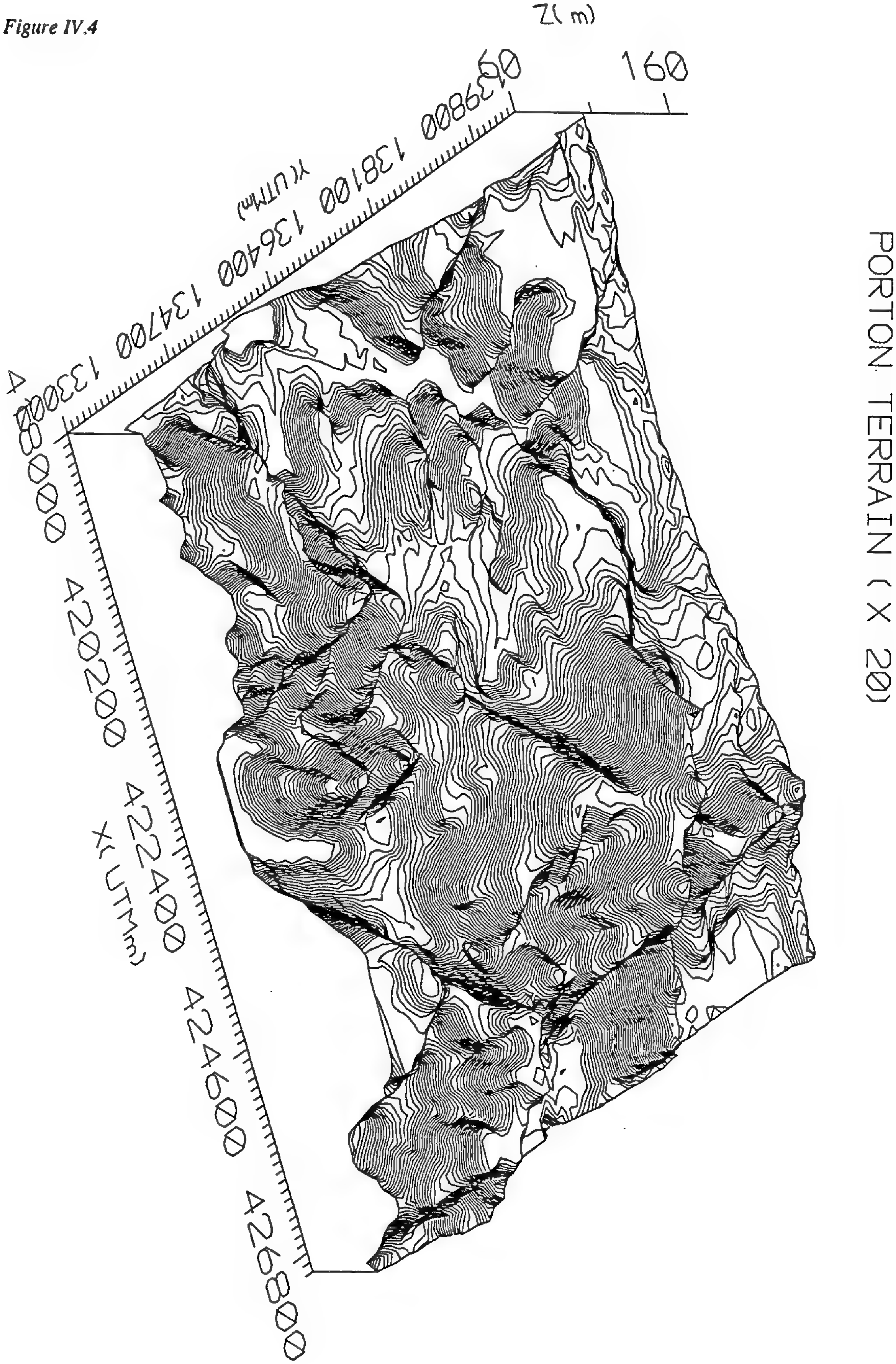
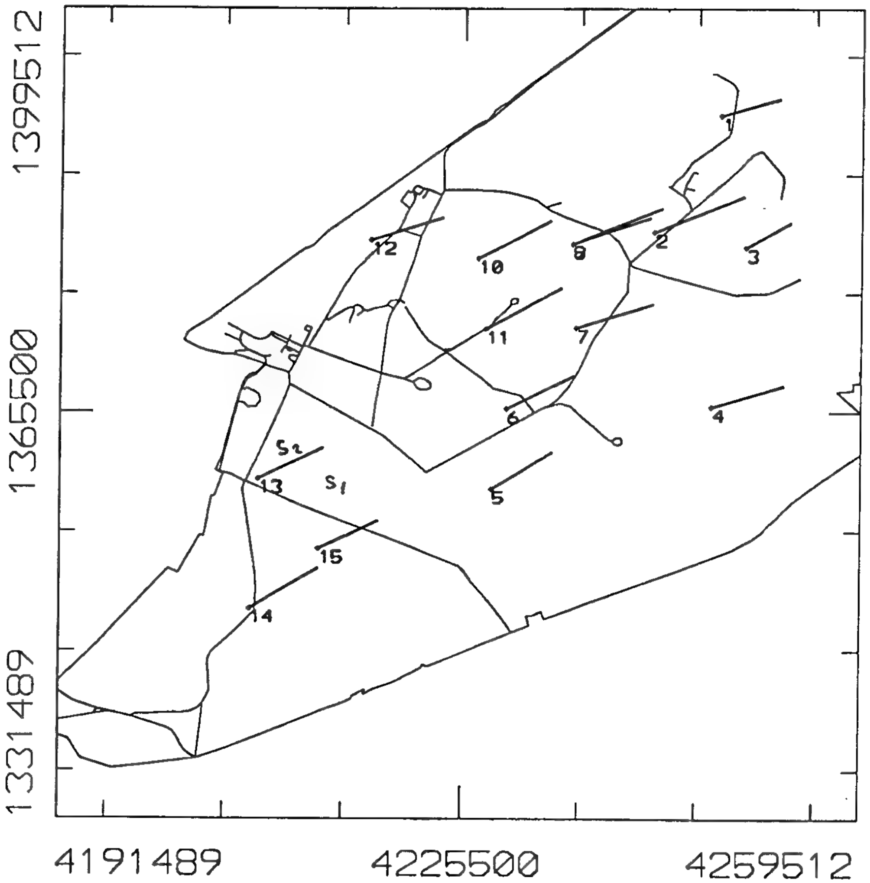


Figure IV.3

Figure IV.4



PORTON TERRAIN (X 20)
Z(m)
60
160
139800 138100 136400 134700 133000
Y(UTMm)
4180000 4202200 4222400 4224600 4226800
X(UTMm)



S,Oct'92

Plot: 16/4/1993

Tick distance: 10000

Value factor: 10000.000

Contrast step: 10000.000

Landscape file: ROADS.BLN

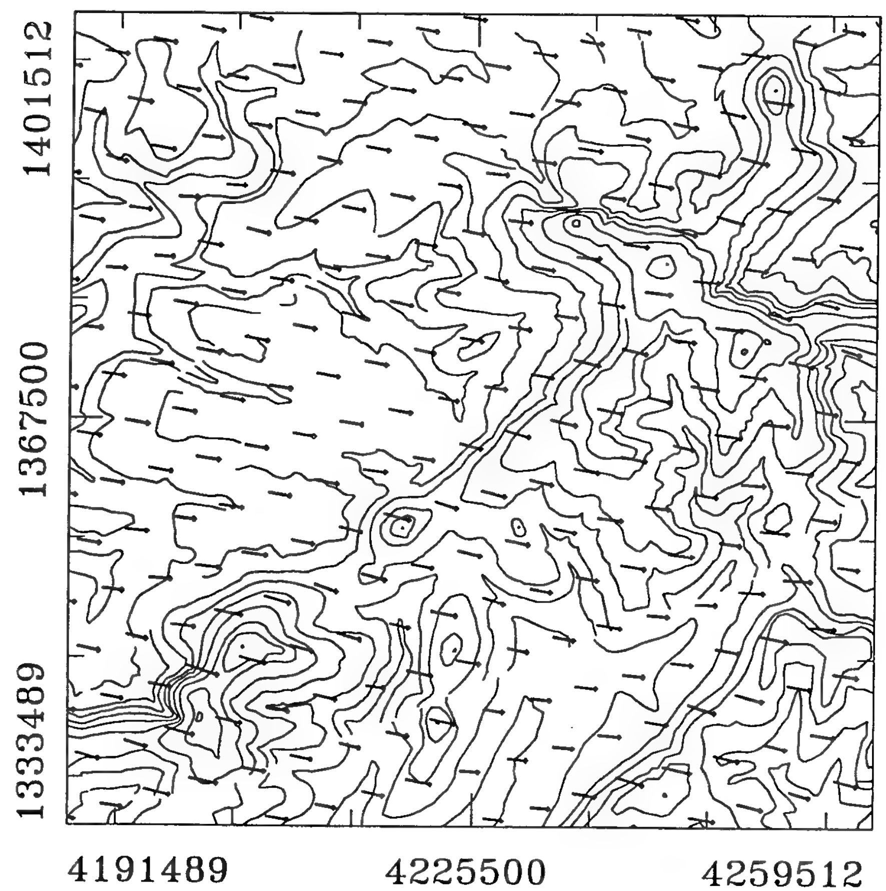
Map file: MASTS.MAP

Data file: 920912.VCT

Record: 1

Time: 12,11:05:00

Figure IV.5



S,Oct'92

Plot: 16/4/1993

PORTON

Tick distance: 10000

Value factor: 1.000

Contrast step: 1.000

Landscape file: TERRAIN.BLN

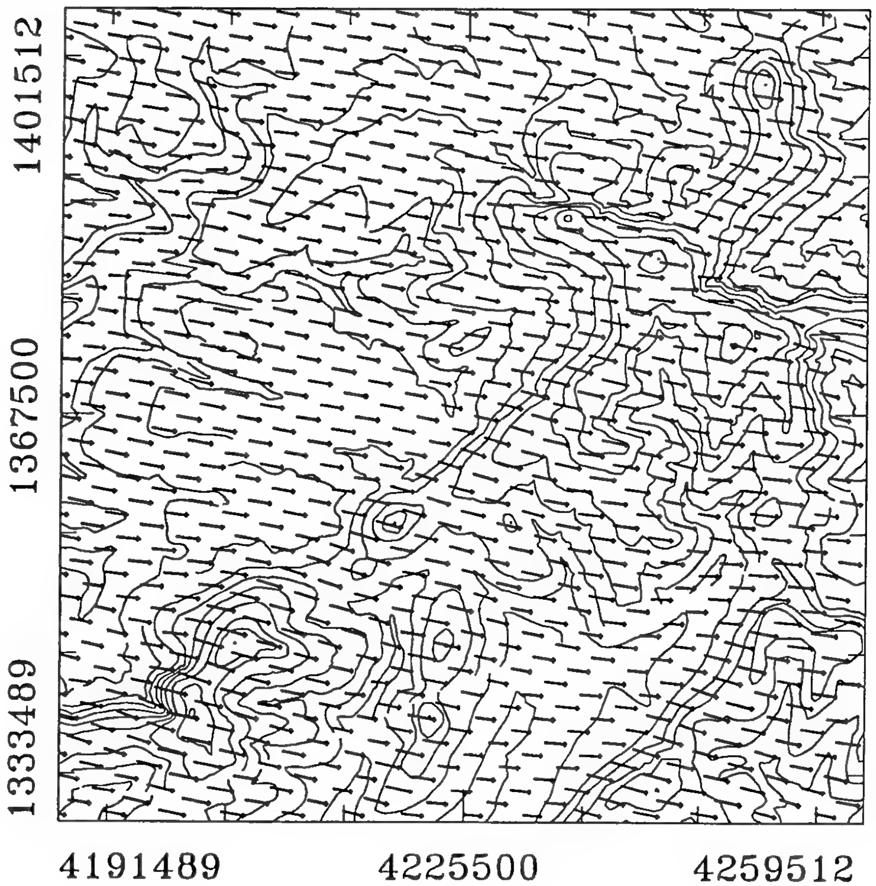
Map file: LINCOM.MAP

Data file: LINCOM.VCT

Record: 3

Time: 0,00:20:00

Figure IV.6



S,Oct'92

Plot: 16/4/1993

PORTON

Tick distance: 10000

Value factor: 1.000

Contrast step: 1.000

Landscape file: TERRAIN.BLN

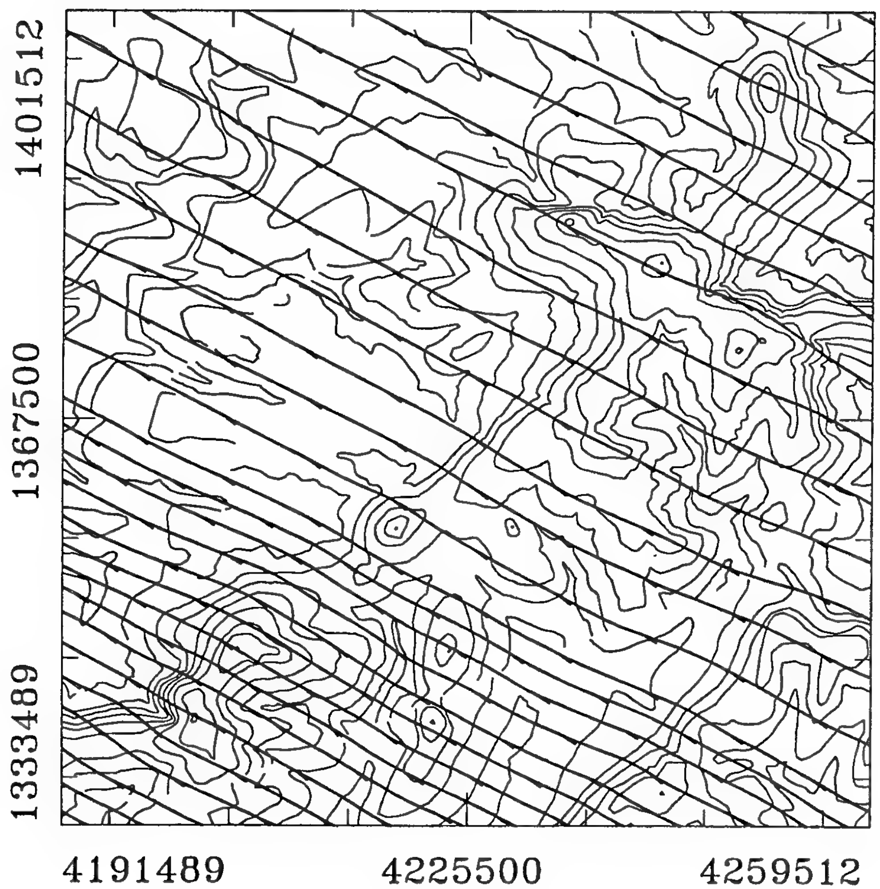
Map file: LINCOM.MAP

Data file: LINCOM.VCT

Record: 3

Time: 0,00:20:00

Figure IV.7



S,Oct'92

Plot: 16/4/1993

PORTON

Tick distance: 10000

Value factor: 1.000

Contrast step: 1.000

Landscape file: TERRAIN.BLN

Map file:

Data file: LINCOM.LNS

Record: 1

Time: 0,00:00:00

Figure IV.8

Appendix IV

Appendix V: The experimental log-book document "RUN_DOC": (version 10.10.1993)

MADONA DISPERSION TRIAL SETUP FILE
compiled by
Kenneth Nyren, FOA and Harald Weber, GMGO

Introduction
This ASCII file contains a compilation of the different runs performed during the ten day experimental period (14.9-23.9 1992) with both continuous smoke and instantaneously generated puffs. The experiments made in parallell with the tracer SF6 are also documented.

The task of collecting the necessary information in this file has been facilitated by personal trial logbooks.

The document is divided in three parts. These are:

* introduction
* syntax definition of the run file
* run documentation file

The purpose is to adopt a simple syntax in the run documentation with key words and values so as to make it machine readable. This has been achieved and proved to be an excellent way to validate the content of the file by plotting different runs on a simple map of the PORTON range.

ALL POSITIONS ARE MEASURED WITH A GPS50 NAVIGATOR FROM GARMIN.
THE OGS 36 MAP DATUM HAS BEEN USED DURING THE TRIALS. THE
POSITION ERROR IS ABOUT 18m, WHICH IS COMFIRMED INDEPENDENTLY
BY COMPARISON WITH THE POSITION INDICATED AT THE TRIG. POINTS
ON THE PORTON RANGE. THUS IT SHOULD BE KEPT IN MIND THAT BETTER
POSITIONAL ACCURACY WAS NOT WITHIN THE SCOPE OF THE EXPERIMENTAL
WORK.

Syntax definition of the run file

The simple syntax of the run documentation file is made by using the Backus-Naur form, syntactic constructs are denoted by English word enclosed between angular brackets < .. >.

```
<run documentation file> ::= <run head> <data block> ...
   ...<run head><data block>

<run head> ::=
     ==> <run code> DURATION <run duration> RELEASE HEIGHT
       <release height> M

<data block> ::=
   RUN <date> <day> <release type>
   RELEASE TIME <release block inst.>|<release block cont.>
   WIND DIRECTION <value in deg>
   SOURCE      <position>
   LIDAR DLR     <position><bearing>
   LIDAR RISO    <position><bearing>
   LIDAR UMIST   <position><bearing>
   VIDEO GMGO    <position><bearing>
   DATA FILES    <file names>
   COMMENTS      <text>
   WEATHER       <text>

<run code> ::= R<julian date>I|C<run no per day>
<run duration> ::= <start time> - <stop time>
<start time>|<stop time> ::= hh:mm
<release height> ::= 9.9
<release block cont.> ::= hh:dd - hh:dd SMOKE SF6
<release block inst.> ::= hh:dd:ss SMOKE SF6
<date> ::= dd.mm.yyyy
<day> ::= MONDAY|TUESDAY ...
<release type> ::= INSTANTANEOUS|CONTINUOUS
<position> ::= :dd_mm.mm_N  ddd_mm_ss.sss_N    Latitude
        :dd_mm.mm_N  ddd_mm_ss.sss_N     Longitude
        99U WB 99999 99999            UTM Coordinate
        999999 999999               BNG Coordinate
<bearing> ::= 999                   Bearing
<file names> ::= <RISO files> <DLR files> <GMGO files>
        <UMIST files>
<GMGO files> ::= <SF6 files> <VIDEO profiles>
```

Run documentation file:

==> R25811 DURATION 13:38 - 14:28 RELEASE HEIGHT 2.3 M

RUN 14.09.1992 MONDAY Instantaneous

```
RELEASE TIME  13:38:30 SMOKE
        13:52:00 SMOKE
        14:00:15 SMOKE
        14:08:00 SMOKE
        14:18:15 SMOKE
        14:28:30 SMOKE

WIND DIRECTION 230

SOURCE     :51_07.54_N  051_07_32.403_N  Latitude
        :01_41.23_W  001_41_13.800_W  Longitude
        30U WB 91875 64735        UTM Coordinate
        421889 136370          BNG Coordinate

LIDAR DLR   :51_07.75_N  051_07_44.996_N  Latitude
        :01_41.02_W  001_41_01.200_W  Longitude
        422133 136760          BNG Coordinate
        30U WB 92113 65129        UTM Coordinate
        170               Bearing

LIDAR RISO   :51_07.71_N  051_07_42.606_N  Latitude
        :01_41.05_W  001_41_02.999_W  Longitude
        422098 136686          BNG Coordinate
        30U WB 92079 65054        UTM Coordinate
        160               Bearing

VIDEO GMGO   :51_07.53_N  051_07_31.799_N  Latitude
        :01_41.25_W  001_41_14.999_W  Longitude
        421866 136351          BNG Coordinate
        30U WB 91852 64716        UTM Coordinate
        110               Bearing

DATA FILES   MAD14A 14-09-92.1
        MAD14B
        MAD14C
        MAD14D
        MAD14E
        MAD14F
```

==> R25812 DURATION 14:34 - 14:34 RELEASE HEIGHT 2.3 M

RUN 14.09.1992 MONDAY Instantaneous

```
RELEASE TIME  14:34:00

WIND DIRECTION 280

SOURCE     :51_07.56_N  051_07_33.598_N  Latitude
        :01_41.22_W  001_41_13.200_W  Longitude
        30U WB 91886 64773        UTM Coordinate
        421901 136407          BNG Coordinate

LIDAR DLR   :51_07.75_N  051_07_44.996_N  Latitude
        :01_41.02_W  001_41_01.200_W  Longitude
        30U WB 92113 65129        UTM Coordinate
        422133 136760          BNG Coordinate
        170               Bearing

LIDAR RISO   :51_07.71_N  051_07_42.606_N  Latitude
        :01_41.05_W  001_41_02.999_W  Longitude
        30U WB 92079 65054        UTM Coordinate
        422098 136686          BNG Coordinate
        160               Bearing

VIDEO GMGO   :51_07.53_N  051_07_31.799_N  Latitude
        :01_41.25_W  001_41_14.999_W  Longitude
        30U WB 91852 64716        UTM Coordinate
        421866 136351          BNG Coordinate
        110               Bearing

DATA FILES   MAD14G
```

==> R258C1 DURATION 15:28 - 17:48 RELEASE HEIGHT 1.0 M

RUN 14.09.1992 MONDAY Continuous

RELEASE TIME 15:28:00 - 17:48:00 SF6
16:30:00 - 17:00:00 SMOKE
17:15:00 - 17:48:00 SMOKE

WIND DIRECTION 280

SOURCE :51_07.57_N 051_07_34.202_N Latitude
:01_41.25_W 001_41_14.999_W Longitude
30U WB 91850 64791 UTM Coordinate
421866 136425 BNG Coordinate

LIDAR DLR :51_07.75_N 051_07_44.996_N Latitude
:01_41.02_W 001_41_01.200_W Longitude
30U WB 92113 65129 UTM Coordinate
422133 136760 BNG Coordinate
190 Bearing

LIDAR RISO :51_07.71_N 051_07_42.606_N Latitude
:01_41.05_W 001_41_02.999_W Longitude
30U WB 92079 65054 UTM Coordinate
422098 136686 BNG Coordinate
190 Bearing

VIDEO GMGO :51_07.75_N 051_07_44.996_N Latitude
:01_41.02_W 001_41_01.200_W Longitude
30U WB 92113 65129 UTM Coordinate
422133 136760 BNG Coordinate
190 Bearing

DATA FILES MAD14H 14-09-92.2 C141612F
MAD14I 14-09-92.3 C141617F
MAD14J 14-09-92.4 C141623F
MAD14K C141627F
C141646F
C141654F
C141701F
C141707F
C141718F
C141724F
C141732F
C141738F

COMMENTS Smoke stopped at 17:02. Restart at 17:15 continuing until 17:43.

WEATHER Trial 1, JD258, 14 Sep had overcast skies producing neutral stability conditions with SW winds of 7 to 10 m/s resulting in a good met. case, a marginal met. modeling situation and good concentration situation.

==>R259I1 DURATION 13:29 - 17:48 RELEASE HEIGHT 2.9 M

RUN 15.09.1992 TUESDAY Instantaneous

RELEASE TIME 13:29:00 SMOKE
13:38:50 SMOKE
13:45:17 SMOKE
13:53:00 SMOKE
14:01:30 SMOKE
14:09:00 SMOKE
14:15:30 SMOKE

WIND DIRECTION 230

SOURCE :51_07.52_N 051_07_31.194_N Latitude
:01_41.16_W 001_41_09.599_W Longitude
30U WB 91957 64700 UTM Coordinate
421971 136333 BNG Coordinate

LIDAR DLR :51_07.74_N 051_07_44.405_N Latitude
:01_41.02_W 001_41_01.200_W Longitude
30U WB 92113 65111 UTM Coordinate
422133 136741 BNG Coordinate
140 Bearing

LIDAR RISO :51_07.71_N 051_07_42.606_N Latitude
:01_41.07_W 001_41_04.199_W Longitude
30U WB 92056 65054 UTM Coordinate
422075 136686 BNG Coordinate
140 Bearing

LIDAR UMIST :51_08.02_N 051_08_01.201_N Latitude
:01_40.81_W 001_40_48.600_W Longitude
30U WB 92349 65634 UTM Coordinate
422375 137261 BNG Coordinate
185 - 145 Bearing

VIDEO GMGO :51_07.51_N 051_07_30.604_N Latitude
:01_41.19_W 001_41_11.399_W Longitude
30U WB 91922 64681 UTM Coordinate
421936 136314 BNG Coordinate
050 Bearing

DATA FILES MAD15A 15-09-92.P1
MAD15B
MAD15C
MAD15D
MAD15E
MAD15F
MAD15G

COMMENTS Puffs passing HS area with Dugway sonics

==> R259C1 DURATION 14:47 - 16:47 RELEASE HEIGHT 1.0 M

RUN 15.09.1992 TUESDAY Continuous

RELEASE TIME 14:47:00 - 16:47:00 SMOKE SF6

WIND DIRECTION 230

SOURCE :51_07.52_N 051_07_31.194_N Latitude
:01_41.16_W 001_41_09.599_W Longitude
30U WB 91957 64700 UTM Coordinate
421971 136333 BNG Coordinate

LIDAR DLR :51_07.74_N 051_07_44.405_N Latitude
:01_41.02_W 001_41_01.200_W Longitude
30U WB 92113 65111 UTM Coordinate
422133 136741 BNG Coordinate
140 Bearing

LIDAR RISO :51_07.71_N 051_07_42.606_N Latitude
:01_41.07_W 001_41_04.199_W Longitude
30U WB 92056 65054 UTM Coordinate
422075 136686 BNG Coordinate
140 Bearing

LIDAR UMIST :51_08.02_N 051_08_01.201_N Latitude
:01_40.81_W 001_40_48.600_W Longitude
30U WB 92349 65634 UTM Coordinate
422375 137261 BNG Coordinate
185 - 145 Bearing

VIDEO GMGO :51_07.71_N 051_07_42.606_N Latitude
:01_41.07_W 001_41_04.199_W Longitude
30U WB 92056 65054 UTM Coordinate
422075 136686 BNG Coordinate
140 Bearing

DATA FILES MAD15H 15-09-92.1 C151504F
MAD15I 15-09-92.2 C151517F
MAD15J 15-09-92.3 C151522F
MAD15K C151525F
MAD15L C151532F
C151538F
C151542F
C151551F
C151614F
C151621F
C151632F
C151642F
C151649F

==> R259I2 DURATION 17:19 - 17:48 RELEASE HEIGHT 2.9M

RUN 15.09.1992 TUESDAY Instantaneous

RELEASE TIME 17:19:00 SMOKE
17:27:00 SMOKE

17:37:30 SMOKE
17:48:10 SMOKE

WIND DIRECTION 230

SOURCE :51_07.52_N 051_07_31.194_N Latitude
:01_41.16_W 001_41_09.599_W Longitude
30U WB 91957 64700 UTM Coordinate
421971 136333 BNG Coordinate

LIDAR DLR :51_07.74_N 051_07_44.405_N Latitude
:01_41.02_W 001_41_01.200_W Longitude
30U WB 92113 65111 UTM Coordinate
422133 136741 BNG Coordinate
140 Bearing

LIDAR RISO :51_07.71_N 051_07_42.606_N Latitude
:01_41.07_W 001_41_04.199_W Longitude
30U WB 92056 65054 UTM Coordinate
422075 136686 BNG Coordinate
140 Bearing

LIDAR UMIST :51_08.02_N 051_08_01.201_N Latitude
:01_40.81_W 001_40_48.600_W Longitude
30U WB 92349 65634 UTM Coordinate
422375 137261 BNG Coordinate
185 - 145 Bearing

VIDEO GMGO :51_07.51_N 051_07_30.604_N Latitude
:01_41.19_W 001_41_11.399_W Longitude
30U WB 91922 64681 UTM Coordinate
421936 136314 BNG Coordinate
050 Bearing

DATA FILES MAD15M 15-09-92.P1
-- 15-09-92.P2
--
MAD15N

COMMENTS Only the first puff and the last puff where traced by LIDAR RISO

WEATHER Trial 2, JD259, 15 Sep had overcast skies again producing neutral and some unstable conditions with SW winds 8 to 5 m/s resulting in a good met. case, a marginal met. modeling situation, and good concentration situation.

==> R260C1 DURATION 13:31 - 15:54 RELEASE HEIGHT 1 M

RUN 16.09.1992 WEDNESDAY Continuous

RELEASE TIME 13:31 - 15:54 SF6

WIND DIRECTION 130

SOURCE :51_07.80_N 051_07_48.003_N Latitude
:01_39.92_W 001_39_55.199_W Longitude
30U WB 93394 65245 UTM Coordinate
423415 136858 BNG Coordinate

DATA FILES C161350F
C161417F
C161427F
C161439F
C161503F
C161520F
C161542F

COMMENTS This continuous SF6 release run in parallell with the following instantaneous smoke release.

==> R260I1 DURATION 14:04 - 15:02 RELEASE HEIGHT 1 M

RUN 16.09.1992 WEDNESDAY Instantaneous

RELEASE TIME 14:04:00 SMOKE
14:34:45 SMOKE
14:51:20 SMOKE
15:02:10 SMOKE

WIND DIRECTION 130

SOURCE :51_07.80_N 051_07_48.003_N Latitude
:01_39.92_W 001_39_55.199_W Longitude
30U WB 93394 65245 UTM Coordinate
423415 136858 BNG Coordinate

LIDAR DLR :51_07.78_N 051_07_46.795_N Latitude
:01_39.89_W 001_39_53.399_W Longitude
30U WB 93429 65208 UTM Coordinate
423450 136821 BNG Coordinate
302 Bearing

LIDAR RISO :51_07.74_N 051_07_44.405_N Latitude
:01_40.27_W 001_40_16.199_W Longitude
30U WB 92988 65126 UTM Coordinate
423007 136745 BNG Coordinate
053 Bearing

VIDEO GMGO :51_07.78_N 051_07_46.795_N Latitude
:01_39.89_W 001_39_53.399_W Longitude
30U WB 93429 65208 UTM Coordinate
423450 136821 BNG Coordinate
302 Bearing

DATA FILES MAD16A 16-09-92.P1
MAD16B
MAD16C
MAD16D

COMMENTS DLR LIDAR FROM BEHIND AND 14:04:00 AT 51_07.78_N
1_39.92_W ONLY. FIRST PUFF 5-6 M ABOVE GROUND

==> R260I2 DURATION 16:00 - 18:42 RELEASE HEIGHT 1.0

RUN 16.09.1992 WEDNESDAY Instantaneous

RELEASE TIME 16:00:00 SMOKE
16:15:30 SMOKE
16:26:00 SMOKE SF6
16:39:15 SMOKE SF6
16:52:15 SMOKE SF6
17:04:30 SMOKE SF6
17:18:00 SMOKE SF6
17:30:00 SMOKE SF6
17:48:45 SMOKE SF6
18:12:50 SMOKE SF6
18:42:32 SMOKE SF6

WIND DIRECTION 135

SOURCE :51_07.80_N 051_07_48.003_N Latitude
:01_39.92_W 001_39_55.199_W Longitude
30U WB 93394 65245 UTM Coordinate
423415 136858 BNG Coordinate

LIDAR DLR :51_07.78_N 051_07_46.795_N Latitude
:01_39.89_W 001_39_53.399_W Longitude
30U WB 93429 65208 UTM Coordinate
423450 136821 BNG Coordinate
350 Bearing

LIDAR RISO :51_07.74_N 051_07_44.405_N Latitude
:01_40.27_W 001_40_16.199_W Longitude
30U WB 92988 65126 UTM Coordinate
423007 136745 BNG Coordinate
053 Bearing

LIDAR UMIST :51_08.02_N 051_08_01.201_N Latitude
:01_40.81_W 001_40_48.600_W Longitude
30U WB 92349 65634 UTM Coordinate
422375 137261 BNG Coordinate
185 - 145 Bearing

VIDEO GMGO :51_07.78_N 051_07_46.795_N Latitude
:01_39.89_W 001_39_53.399_W Longitude
30U WB 93429 65208 UTM Coordinate
423450 136821 BNG Coordinate
350 Bearing

DATA FILES MAD16G 16-09-92.P1 C161652P
MAD16H C161704P
MAD16I C161718P C161804F
MAD16J C161813P
MAD16K C161848P
MAD16L C161858P
MAD16M
MAD16N
MAD16O

COMMENTS 17:04 WINDSPEED 0.5 M/S WINDDIR 220 DEG
17:20-17:44 UMIST LIDAR SCANNING IN 095-055 DEG

WEATHER Trial 3, JD260, 16 Sep had clear skies producing,

unstable, neutral and stable conditions with SE winds
5 m/s resulting in a very good met. case, an excellent
modeling situation, and good puff concentrations.

==>R26110 DURATION - RELEASE HEIGHT - M

NORUN 17.09.1992 THURSDAY

WEATHER: Trial 4, JD261, 17 Sep had overcast skies producing
neutral stability conditions and E and SE winds of
5 to 1 m/s resulting in a good met for modeling,
but poor met conditions for tracer releases - unable
to maintain a steady wind direction thereby
compromising the positioning of the tracer/lidar sets.

==> R262C1 DURATION 13:45 - 14:13 RELEASE HEIGHT 1 M

RUN 18.09.1992 FRIDAY Continuous

RELEASE TIME 13:35:00 - 14:40:00 SMOKE
13:35:00 - 16:50:00 SF6

WIND DIRECTION 225

SOURCE :51_07.61_N 051_07_36.605_N Latitude
:01_41.24_W 001_41_14.400_W Longitude
30U WB 91861 64865 UTM Coordinate
421877 136499 BNG Coordinate

LIDAR DLR :51_07.75_N 051_07_44.996_N Latitude
:01_41.01_W 001_41_00.600_W Longitude
30U WB 92124 65129 UTM Coordinate
422144 136760 BNG Coordinate
087 Bearing

DATA FILES 18-09-92.1 C181402F
C181406F
C181414F
C181426F
C181434F
C181450F
C181537F

COMMENTS Owing to precipitation RISO LIDAR unable to run

==> R262I1 DURATION 17:02 - 17:32 RELEASE HEIGHT 2.3 M

RUN 18.09.1992 FRIDAY Instantaneous

RELEASE HEIGHT 2.3 M

RELEASE TIME 17:02:20 SMOKE
17:13:00 SMOKE
17:19:30 SMOKE
17:32:00 SMOKE SF6

WIND DIRECTION 220

SOURCE :51_07.43_N 051_07_25.797_N Latitude
:01_40.75_W 001_40_44.999_W Longitude
30U WB 92438 64541 UTM Coordinate
422450 136168 BNG Coordinate

LIDAR DLR :51_07.75_N 051_07_44.996_N Latitude
:01_41.01_W 001_41_00.600_W Longitude
30U WB 92124 65129 UTM Coordinate
422144 136760 BNG Coordinate
087 Bearing

LIDAR RISO :51_07.74_N 051_07_44.405_N Latitude
:01_40.88_W 001_40_52.799_W Longitude
30U WB 92276 65113 UTM Coordinate
422296 136742 BNG Coordinate
065 Bearing

LIDAR UMIST :51_08.02_N 051_08_01.201_N Latitude
:01_40.81_W 001_40_48.600_W Longitude
30U WB 92349 65634 UTM Coordinate
422375 137261 BNG Coordinate
185 - 145 Bearing

VIDEO GMGO :51_07.75_N 051_07_44.996_N Latitude
:01_41.02_W 001_41_01.200_W Longitude
30U WB 92113 65129 UTM Coordinate
422133 136760 BNG Coordinate
050 Bearing

DATA FILES 18-09-92.P1

==>R262C2 DURATION 17:42 - 18:42 RELEASE HEIGHT 1.0 M

RUN 18.09.1992 FRIDAY Continuous

RELEASE TIME 17:42:00 - 18:42:00 SMOKE SF6

WIND DIRECTION 180

SOURCE :51_07.50_N 051_07_29.999_N Latitude
:01_40.56_W 001_40_33.599_W Longitude
30U WB 92657 64675 UTM Coordinate
422671 136299 BNG Coordinate

LIDAR DLR :51_07.75_N 051_07_44.996_N Latitude
:01_41.01_W 001_41_00.600_W Longitude
30U WB 92124 65129 UTM Coordinate
422144 136760 BNG Coordinate
087 Bearing

LIDAR RISO :51_07.74_N 051_07_44.405_N Latitude
:01_40.88_W 001_40_52.799_W Longitude
30U WB 92276 65113 UTM Coordinate
422296 136742 BNG Coordinate
065 Bearing

LIDAR UMIST :51_08.02_N 051_08_01.201_N Latitude
:01_40.81_W 001_40_48.600_W Longitude
30U WB 92349 65634 UTM Coordinate
422375 137261 BNG Coordinate
085 - 125 Bearing

VIDEO GMGO :51_07.75_N 051_07_44.996_N Latitude
:01_41.01_W 001_41_00.600_W Longitude
30U WB 92124 65129 UTM Coordinate
422144 136760 BNG Coordinate
087 Bearing

DATA FILES MAD18A 18-09-92.P1 C181803F
C181810F
C181824F
C181837F
C181858F

WEATHER Trial 5, JD262, 18 Sep hade overcast skies producing
neutral stability conditions with SE winds of 4 to
1 m/s resulting in a very good met and modelling
situation and good concentration situation.

==> R263I1 DURATION 13:15 - 14:01 RELEASE HEIGHT 6 M

RUN 19.09.1992 SATURDAY Instantaneous

RELEASE TIME 13:15:00 SMOKE SF6
13:25:00 SMOKE SF6
13:36:00 SMOKE SF6
13:47:23 SMOKE SF6
14:01:00 SMOKE SF6
WIND DIRECTION 300

SOURCE :51_07.69_N 051_07_41.398_N Latitude
:01_41.27_W 001_41_16.199_W Longitude
30U WB 91823 65012 UTM Coordinate
421842 136647 BNG Coordinate

LIDAR DLR :51_07.75_N 051_07_44.996_N Latitude
:01_41.01_W 001_41_00.600_W Longitude
30U WB 92124 65129 UTM Coordinate
422144 136760 BNG Coordinate
221 Bearing

LIDAR RISO :51_07.69_N 051_07_41.398_N Latitude
:01_41.04_W 001_41_02.400_W Longitude
30U WB 92091 65017 UTM Coordinate
422110 136648 BNG Coordinate
221 Bearing

VIDEO GMGO :51_07.70_N 051_07_42.002_N Latitude
:01_41.29_W 001_41_17.399_W Longitude
30U WB 91799 65031 UTM Coordinate
421818 136666 BNG Coordinate
135 Bearing

DATA FILES MAD19A 19-09-92.1 C191325P
MAD19B C191336P
MAD19C C191347P
MAD19D C191401P
MAD19E

==>R263C1 DURATION 14:50 - 15:55 RELEASE HEIGHT 1.0 M

RUN 19.09.1992 SATURDAY Continuous

RELEASE TIME 14:50:00 - 15:55:00 SMOKE SF6

WIND DIRECTION 270

SOURCE :51_07.81_N 051_07_48.594_N Latitude
:01_41.12_W 001_41_07.199_W Longitude
30U WB 91994 65238 UTM Coordinate
422016 136870 BNG Coordinate

LIDAR DLR :51_07.75_N 051_07_44.996_N Latitude
:01_40.77_W 001_40_46.199_W Longitude
30U WB 92404 65134 UTM Coordinate
422424 136761 BNG Coordinate
003 Bearing

LIDAR RISO :51_07.75_N 051_07_44.996_N Latitude
:01_40.77_W 001_40_46.199_W Longitude
30U WB 92404 65134 UTM Coordinate
422424 136761 BNG Coordinate
003 Bearing

VIDEO GMGO :51_07.75_N 051_07_44.996_N Latitude
:01_40.77_W 001_40_46.199_W Longitude
30U WB 92404 65134 UTM Coordinate
422424 136761 BNG Coordinate
003 Bearing

DATA FILES MAD19E 19-09-92.1 C191454F
C191516F
C191521F
C191524F
C191529F
C191548F
C191600F

==> R263I2 DURATION 16:10 - 16:26 RELEASE HEIGHT 6 M

RUN 19.09.1992 SATURDAY Instantaneous

RELEASE HEIGHT 6 M

RELEASE TIME 16:10:40 SMOKE SF6
16:20:30 SMOKE SF6
16:26:35 SMOKE SF6

WIND DIRECTION 280

SOURCE :51_07.81_N 051_07_48.594_N Latitude
:01_41.12_W 001_41_07.199_W Longitude
30U WB 91994 65238 UTM Coordinate
422016 136870 BNG Coordinate

LIDAR DLR :51_07.95_N 051_07_56.998_N Latitude
:01_40.67_W 001_40_40.199_W Longitude
30U WB 92514 65507 UTM Coordinate
422539 137132 BNG Coordinate
330 Bearing

LIDAR RISO :51_07.95_N 051_07_56.998_N Latitude
:01_40.67_W 001_40_40.199_W Longitude
30U WB 92514 65507 UTM Coordinate
422539 137132 BNG Coordinate
330 Bearing

DATA FILES MAD19F 19-09-92.1
-- C191620P
MAD19G

==> R263I3 DURATION 17:35 - 18:30 RELEASE HEIGHT 6 M

RUN 19.09.1992 SATURDAY Instantaneous

RELEASE TIME 17:35:00 SMOKE
17:49:30 SMOKE
18:01:00 SMOKE
18:14:30 SMOKE
18:23:00 SMOKE
18:30:00 SMOKE

WIND DIRECTION 225

SOURCE :51_08.00_N 051_08_00.006_N Latitude
:01_40.81_W 001_40_48.600_W Longitude
30U WB 92349 65597 UTM Coordinate
422376 137224 BNG Coordinate

LIDAR DLR :51_07.95_N 051_07_56.998_N Latitude
:01_40.67_W 001_40_40.199_W Longitude
30U WB 92514 65507 UTM Coordinate
422539 137132 BNG Coordinate
330 Bearing

LIDAR RISO :51_07.95_N 051_07_56.998_N Latitude
:01_40.67_W 001_40_40.199_W Longitude
30U WB 92514 65507 UTM Coordinate
422539 137132 BNG Coordinate
330 Bearing

VIDEO CBDE :51_07.73_N 051_07_43.801_N Latitude
:01_40.28_W 001_40_16.799_W Longitude
30U WB 92976 65107 UTM Coordinate
422996 136727 BNG Coordinate
320 Bearing

DATA FILES -- 19-09-92.1
MAD19H C191745F
MAD19I
MAD19J
MAD19K
MAD19L

COMMENTS FROM 17:50 STABLE CONDITIONS High extinction and low backscatter

WEATHER Trial 6, JD263, 19 Sep had overcast skies with some breaks producing instable, neutral and stable stability conditions with W and SW winds of 5 to 1 m/s resulting in very good met and modelling and good puff concentration conditions.

==> R264C1 DURATION 11:40 - 13:20 RELEASE HEIGHT 1 M

RUN 20.09.1992 SUNDAY Continuous

RELEASE TIME 11:40:00 - 13:20:00 SMOKE SF6

WIND DIRECTION 225

SOURCE :51_07.42_N 051_07_25.193_N Latitude
:01_41.04_W 001_41_02.400_W Longitude
30U WB 92100 64517 UTM Coordinate
422112 136148 BNG Coordinate

LIDAR DLR :51_07.75_N 051_07_44.996_N Latitude
:01_41.02_W 001_41_01.200_W Longitude
30U WB 92113 65129 UTM Coordinate
422133 136760 BNG Coordinate
120 Bearing

LIDAR RISO :51_07.75_N 051_07_44.996_N Latitude
:01_40.49_W 001_40_29.399_W Longitude
30U WB 92731 65140 UTM Coordinate
422751 136762 BNG Coordinate
310 Bearing

VIDEO GMGO :51_07.75_N 051_07_44.996_N Latitude
:01_41.02_W 001_41_01.200_W Longitude
30U WB 92113 6512 9 UTM Coordinate
422133 136760 BNG Coordinate
120 Bearing

DATA FILES MAD20A 20-09-92.1 C201141F
C201153F
C201205F
C201218F
C201225F
C201240F
MAD20B C201246F
C201253F

COMMENTS 12:07--12:29 Very bad lidar profiles caused by smoke into LIDAR. RISO LIDAR position uncertain
12:47--13:01 Not too bad

==> R264I1 DURATION 14:55 - 15:30 RELEASE HEIGHT 6 M

RUN 20.09.1992 SUNDAY Instantaneous

RELEASE TIME 14:55:22 SMOKE
15:13:30 SMOKE SF6
15:30:00 SMOKE SF6

WIND DIRECTION 225

SOURCE :51_07.53_N 051_07_31.799_N Latitude
:01_41.16_W 001_41_09.599_W Longitude
30U WB 91957 64718 UTM Coordinate
421971 136351 BNG Coordinate LIDAR DLR
:51_07.75_N 051_07_44.996_N Latitude
:01_41.02_W 001_41_01.200_W Longitude
30U WB 92113 65129 UTM Coordinate
422133 136760 BNG Coordinate
120 Bearing

LIDAR RISO :51_07.70_N 051_07_42.002_N Latitude
:01_41.03_W 001_41_01.800_W Longitude
30U WB 92103 65036 UTM Coordinate
422121 136667 BNG Coordinate
120 Bearing

VIDEO GMGO :51_07.75_N 051_07_44.996_N Latitude
:01_41.02_W 001_41_01.200_W Longitude
30U WB 92113 65129 UTM Coordinate
422133 136760 BNG Coordinate
120 Bearing

DATA FILES MAD20C 20-09-92.1
MAD20D C201513P
MAD20E

COMMENTS 15:30 THE HOLLY PUFF WAS RELEASED

==>R264C2 RELEASE TIME 15:40-16:00 RELEASE HEIGHT1 M

RUN 20.09.1992 SUNDAY Continuous

RELEASE HEIGHT 1 M

RELEASE TIME 15:40:00 - 16:00:00 SF6

WIND DIRECTION 225

SOURCE :51_07.42_N 051_07_25.193_N Latitude
:01_41.04_W 001_41_02.400_W Longitude
30U WB 92100 64517 UTM Coordinate
422112 136148 BNG Coordinate

LIDAR DLR :51_07.75_N 051_07_44.996_N Latitude
:01_41.02_W 001_41_01.200_W Longitude
30U WB 92113 65129 UTM Coordinate
422133 136760 BNG Coordinate
120 Bearing

LIDAR RISO :51_07.75_N 051_07_44.996_N Latitude
:01_40.49_W 001_40_29.399_W Longitude
30U WB 92731 65140 UTM Coordinate
422751 136762 BNG Coordinate
310 Bearing

VIDEO GMGO :51_07.75_N 051_07_44.996_N Latitude
:01_41.02_W 001_41_01.200_W Longitude
30U WB 92113 65129 UTM Coordinate
422133 136760 BNG Coordinate

DATA FILES C201549F
C201554F

==> R26412 DURATION 18:32 - 19:10 RELEASE HEIGHT 1 M

RUN 20.09.1992 SUNDAY Instantaneous

RELEASE TIME 18:32:00 SMOKE
18:41:00 SMOKE
18:49:00 SMOKE
18:56:00 SMOKE
19:04:00 SMOKE
19:10:00 SMOKE

WIND DIRECTION 160

SOURCE :51_08.54_N 051_08_32.402_N Latitude
:01_39.97_W 001_39_58.200_W Longitude
30U WB 93311 66615 UTM Coordinate
423350 138229 BNG Coordinate

LIDAR RISO :51_08.45_N 051_08_27.005_N Latitude
:01_39.89_W 001_39_53.399_W Longitude
30U WB 93407 66450 UTM Coordinate
423444 138063 BNG Coordinate
296 Bearing

VIDEO CBDE :51_08.51_N 051_08_30.603_N Latitude
:01_39.90_W 001_39_53.999_W Longitude
30U WB 93393 66561 UTM Coordinate
423432 138174 BNG Coordinate
307 Bearing

DATA FILES MAD20J 20-09-92.1 (Bearing 220)
MAD20K (Bearing 260)
MAD20L
MAD20M
MAD20N
MAD20O

COMMENTS 18:30 transition from neutral to stable during the instantaneous releases.

WEATHER Trial 7, JD264, 20 Sep had overcast skies producing neutral and stable conditions with SW winds of 5 to 1 m/s resulting in very good mat and modelling and marginal plume and good puff conditions.

==> R26511 DURATION 13:02 - 14:04 RELEASE HEIGHT 1 M

RUN 21.09.1992 MONDAY Instantaneous

RELEASE TIME 13:02:30 SMOKE
13:22:30 SMOKE SF6
13:32:40 SMOKE SF6
13:41:30 SMOKE SF6
13:51:20 SMOKE SF6
14:04:30 SMOKE SF6

WIND DIRECTION 070

SOURCE :51_08.37_N 051_08_22.198_N Latitude
:01_39.53_W 001_39_31.799_W Longitude
30U WB 93829 66309 UTM Coordinate
423865 137917 BNG Coordinate

LIDAR DLR :51_08.39_N 051_08_23.393_N Latitude
:01_39.88_W 001_39_52.800_W Longitude
30U WB 93421 66339 UTM Coordinate
423457 137952 BNG Coordinate
164 Bearing

LIDAR RISO :51_08.39_N 051_08_23.393_N Latitude
:01_39.88_W 001_39_52.800_W Longitude
30U WB 93421 66339 UTM Coordinate
423457 137952 BNG Coordinate
164 Bearing

VIDEO CBDE :51_08.40_N 051_08_23.997_N Latitude
:01_39.53_W 001_39_31.799_W Longitude
30U WB 93828 66365 UTM Coordinate
423865 137972 BNG Coordinate
150 Bearing

DATA FILES -- 21-09-92.1
MAD21A C211322P
MAD21B C211333P
MAD21C C211341P
MAD21D
MAD21E

==> R265C1 DURATION 14:10 - 15:00 RELEASE HEIGHT 1 M

RUN 21.09.1992 MONDAY Continuous

RELEASE TIME 14:10:00 - 15:00:00 SMOKE SF6

WIND DIRECTION 120

SOURCE :51_08.37_N 051_08_22.198_N Latitude
:01_39.50_W 001_39_29.999_W Longitude
30U WB 93864 66310 UTM Coordinate
423900 137917 BNG Coordinate

LIDAR DLR :51_08.51_N 051_08_30.603_N Latitude
:01_39.82_W 001_39_49.200_W Longitude
30U WB 93486 66563 UTM Coordinate
423526 138175 BNG Coordinate
190 Bearing

LIDAR RISO :51_08.49_N 051_08_29.394_N Latitude
:01_39.75_W 001_39_45.000_W Longitude
30U WB 93569 66527 UTM Coordinate
423607 138138 BNG Coordinate

203 Bearing

DATA FILES MAD21F 21-09-92.2 C211434F
C211444F
C211510F

COMMENTS Good profiles despite smoke into RISO LIDAR generating some bad profiles. Profiles in MAD21F fr 12:42--14:59

==> R265C2 DURATION 15:20 - 16:51 RELEASE HEIGHT 1 M

RUN 21.09.1992 MONDAY Continuous

RELEASE TIME 15:20:00 - 16:51:00 SMOKE SF6

WIND DIRECTION 120

SOURCE :51_08.37_N 051_08_22.198_N Latitude
:01_39.50_W 001_39_29.999_W Longitude
30U WB 93864 66310 UTM Coordinate
423900 137917 BNG Coordinate

LIDAR DLR :51_08.52_N 051_08_31.193_N Latitude
:01_39.70_W 001_39_41.999_W Longitude
30U WB 93626 66584 UTM Coordinate
423665 138193 BNG Coordinate
190 Bearing

LIDAR RISO :51_08.52_N 051_08_31.193_N Latitude
:01_39.70_W 001_39_41.999_W Longitude
30U WB 93626 66584 UTM Coordinate
423665 138193 BNG Coordinate
203 Bearing

DATA FILES MAD21G 21-09-92.3 C211533F
MAD21H C211540F
MAD21I C211552F
MAD21J C211553F
C211615F
C211619F
C211633F
C211634F
C211644F
C211645F
C211650F

COMMENTS In profile data file H, I and J smoke into the RISO LIDAR. Profile data follows.

DATA FILES MAD21G during 15:19--15:43
MAD21H 15:45--16:17
MAD21I 16:18--16:40
MAD21J 16:14--16:51

==> R265C3 DURATION 17:30 - 18:16 RELEASE HEIGHT 1 M

RUN 21.09.1992 MONDAY Continuous

RELEASE HEIGHT 1 M

RELEASE TIME 17:19:00 - 18:16:00 SMOKE SF6

WIND DIRECTION 140

SOURCE :51_08.21_N 051_08_12.599_N Latitude
:01_39.47_W 001_39_28.200_W Longitude
30U WB 93905 66014 UTM Coordinate
423936 137620 BNG Coordinate

LIDAR DLR :51_08.37_N 051_08_22.198_N Latitude
:01_39.50_W 001_39_29.999_W Longitude
30U WB 93864 66310 UTM Coordinate
423900 137917 BNG Coordinate
220 Bearing

LIDAR RISO :51_08.41_N 051_08_24.602_N Latitude
:01_39.53_W 001_39_31.799_W Longitude
30U WB 93828 66384 UTM Coordinate
423865 137991 BNG Coordinate
243 Bearing

DATA FILES MAD21K 21-09-92.3 C211724F
C211732F
C211743F
C211749F
C211806F
C211819F

WEATHER Trial 8, JD265, 21 Sep had overcast skies producing neutral/stable conditions with E winds of 4 to 5 m/s resulting in in very good met and modelling situations and marginal plume and puff concentration conditions.

==> R26611 DURATION 13:41 - 14:29 RELEASE HEIGHT 2.3 M

RUN 22.09.1992 TUESDAY Instantaneous

RELEASE TIME 13:41:25 SMOKE SF6
13:52:13 SMOKE SF6
14:07:45 SMOKE SF6
14:18:35 SMOKE SF6
14:29:00 SMOKE SF6

WIND DIRECTION 270

SOURCE :51_08.14_N 051_08_08.397_N Latitude
:01_40.31_W 001_40_18.599_W Longitude
30U WB 92928 65867 UTM Coordinate
422957 137486 BNG Coordinate

LIDAR DLR :51_08.14_N 051_08_08.397_N Latitude
:01_40.04_W 001_40_02.400_W Longitude
30U WB 93242 65872 UTM Coordinate
423272 137488 BNG Coordinate
200 Bearing

LIDAR RISO :51_08.13_N 051_08_07.806_N Latitude
:01_40.06_W 001_40_03.599_W Longitude
30U WB 93219 65854 UTM Coordinate
423249 137469 BNG Coordinate
235 Bearing

DATA FILES MAD22A 22-09-92.P1 C221341P
MAD22B C221352P
MAD22C C221429P
MAD22D
MAD22E

==> R2266C1 DURATION 14:45 - 16:15 RELEASE HEIGHT 1 M

RUN 22.09.1992 TUESDAY Continuous

RELEASE TIME 14:45:00 - 16:15:00

WIND DIRECTION 270

SOURCE :51_08.15_N 051_08_09.001_N Latitude
:01_40.32_W 001_40_19.199_W Longitude
30U WB 92916 65885 UTM Coordinate
422946 137505 BNG Coordinate

LIDAR DLR :51_08.14_N 051_08_08.397_N Latitude
:01_40.04_W 001_40_02.400_W Longitude
30U WB 93242 65872 UTM Coordinate
423272 137488 BNG Coordinate
200 Bearing

LIDAR RISO :51_08.13_N 051_08_07.806_N Latitude
:01_40.06_W 001_40_03.599_W Longitude
30U WB 93219 65854 UTM Coordinate
423249 137469 BNG Coordinate
235 Bearing

DATA FILES MAD22F 22-09-92.1 C221458F
C221502F
C221509F
C221518F
C221525F
C221527F
C221532F
C221538F
C221548F
C221558F
C221604F
C221610F
C221614F
C221620F

COMMENTS Very good scanning results from RISO LIDAR. MAD-22F contains scanned profiles fr 14:51--16:31

WEATHER Trial 9, JD266, 22 Sep had overcast skies with occassional rain producing neutral to stable conditions with NW winds of 4 to 1 m/s and "so-so" met and modelling and good concentration

conditions.

==> R267I1 DURATION 12:28 - 13:08 RELEASE HEIGHT 2.3 M

RUN 23.09.1992 WEDNESDAY Instantaneous

RELEASE TIME 12:28:00 SMOKE SF6
12:38:30 SMOKE SF6
12:46:30 SMOKE SF6
12:54:00 SMOKE SF6
13:08:30 SMOKE SF6

WIND DIRECTION 260

SOURCE :51_08.14_N 051_08_08.397_N Latitude
:01_40.31_W 001_40_18.599_W Longitude
30U WB 92928 65867 UTM Coordinate
422957 137486 BNG Coordinate

LIDAR DLR :51_08.09_N 051_08_05.403_N Latitude
:01_40.01_W 001_40_00.599_W Longitude
30U WB 93279 65780 UTM Coordinate
423308 137395 BNG Coordinate
315 Bearing

LIDAR RISO :51_08.10_N 051_08_05.993_N Latitude
:01_40.00_W 001_40_00.000_W Longitude
30U WB 93290 65799 UTM Coordinate
423319 137414 BNG Coordinate
349 Bearing

DATA FILES -- 23-09-92.1
MAD23B
MAD23C C231246P
MAD23D
MAD23E C231308P

COMMENTS RISO LIDAR poor profiles due to smoke into the instrument

==> R267C1 DURATION 13:25 - 17:28 RELEASE HEIGHT 1 M

RUN 23.09.1992 WEDNESDAY Continuous

RELEASE TIME 13:25:00 - 17:28:00 SMOKE SF6

WIND DIRECTION 260

SOURCE :51_08.17_N 051_08_10.196_N Latitude
:01_40.30_W 001_40_17.999_W Longitude
30U WB 92938 65922 UTM Coordinate
422969 137542 BNG Coordinate

LIDAR DLR :51_08.09_N 051_08_05.403_N Latitude
:01_40.01_W 001_40_00.599_W Longitude
30U WB 93279 65780 UTM Coordinate
423308 137395 BNG Coordinate
315 Bearing

LIDAR RISO :51_08.10_N 051_08_05.993_N Latitude
:01_40.00_W 001_40_00.000_W Longitude
30U WB 93290 65799 UTM Coordinate
423319 137414 BNG Coordinate
349 Bearing

DATA FILES 23-09-92.2 C231329F
MAD23F C231335F
C231342F
C231342F
C231359F
C231413F
C231420F
C231428F
23-09-92.3 C231434F
C231444F
C231453F
C231458F
MAD23G C231505F
C231510F
C231517F
23-09-92.4 C231523F
C231526F
C231535F
C231542F
C231551F
C231556F
C231603F
C231621F
23-09-92.5 C231623F
C231627F
C231635F
C231640F
C231651F
C231655F
C231704F
C231719F
C231722F

COMMENTS RISO LIDAR scanning -2--10 deg. Profiles in MAD23F fr
13:32--14:46 and MAD23G 15:00--17:31

==> R23I02 DURATION 17:36 - 18:01 RELEASE HEIGHT 2.3

RUN 23.09.1992 WEDNESDAY Instantaneous

RELEASE TIME 17:36:30 SMOKE SF6
17:47:30 SMOKE SF6
18:01:00 SMOKE

WIND DIRECTION 260

SOURCE :51_08.14_N 051_08_08.397_N Latitude
:01_40.31_W 001_40_18.599_W Longitude
30U WB 92928 65867 UTM Coordinate
422957 137486 BNG Coordinate

LIDAR DLR :51_08.09_N 051_08_05.403_N Latitude
:01_40.01_W 001_40_00.599_W Longitude
30U WB 93279 65780 UTM Coordinate
423308 137395 BNG Coordinate
315 Bearing

LIDAR RISO :51_08.10_N 051_08_05.993_N Latitude
:01_40.00_W 001_40_00.000_W Longitude
30U WB 93290 65799 UTM Coordinate
423319 137414 BNG Coordinate
349 Bearing

VIDEO GMGO [positioned near by source ?]

DATA FILES MAD23H 23-09-92.6 C231733F
MAD23I 23-09-92.7 C231738F
--

COMMENTS 18:01 SIX GRAND PUFFS WITH 20 SECONDS IN BETWEEN: MADONA GRAND FINAL!

WEATHER Trial 10. JD267, 23 Sep had mostly cloudy skies producing neutral and stable conditions with SW winds of 6 to 8 m/sresulting in good met and modelling and good concentration conditions.

THE MADONA CDROM DATA BASE (VERS 1.01) IS AVAILABLE FROM:
Timothy J.Higgs at CBDE Porton Down, UK
+44-(0)980-613311 fax
email: 100071.2321@compuserve.com

Appendix V

MADONA:
DIFFUSION MEASUREMENTS OF SMOKE PLUMES AND OF SMOKE PUFFS

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1. INTRODUCTION

To accomplish the objective of obtaining a high resolution diffusion data base, the MADONA trials made use of smoke, SF_6 and propylene tracer gases in the dispersion experiments that took place in the terrain influenced wind and turbulence fields over the Porton Down test site.

A total of 27 diffusion experiments were conducted during the days of September 14 to 23 during unstable, neutral and stable atmospheric conditions at downwind distances between 100 and 1000 m from the release point. In total, some 84 instantaneous releases of smoke puffs and 8 continuous hour long lasting combined SF_6 and smoke plume releases were succesfully obtained. This paper describes the dispersion characteristics obtained from the MADONA trials based on the smoke puffs and plume experiments conducted:

Puffs and plumes were generated by mixing liquid $SiCl_4$ (Silicon-tetrachloride) and a 25% solution of NH_4OH (Ammonia) in their proper stoichiometric ratio. Puffs were generated by firing of a two-component cylindrical charge (100 ml of $SiCl_4$ and 320 ml of NH_4OH) with a burster tube filled with plastic explosive. Continuous smoke plumes were generated by mixing the same chemicals into a strong air-jet from two constant flow rate pumps. Depending on the flow rates and the stability of the atmosphere, the puffs and plumes could be made visible kilometers downwind.

Detection of the time and space dependent dispersion were based on two aerosol LIDAR remote sensing systems, one visio-ceilometer (also lidar-based) and one mobile SF_6 real-time flame photometer. The LIDAR systems were positioned at various downwind positions to measure the aerosol backscatter coefficients (air concentration) at lines of sight normal to the smoke and puff centerline travel. While the visio-

ceilometer

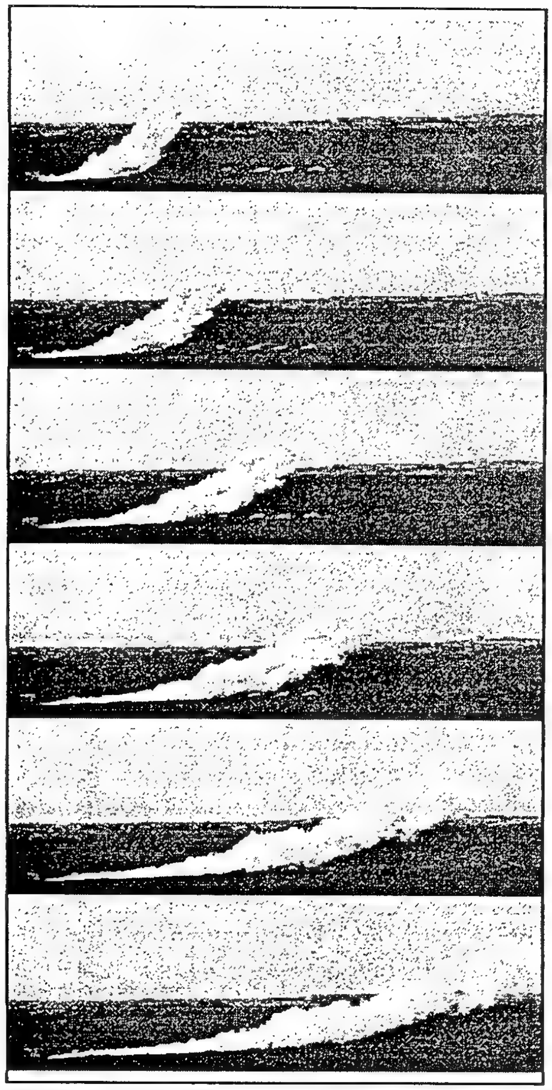

Figure 1. Ground-level instantaneous puff release during stable stratification exhibiting vertical shear.

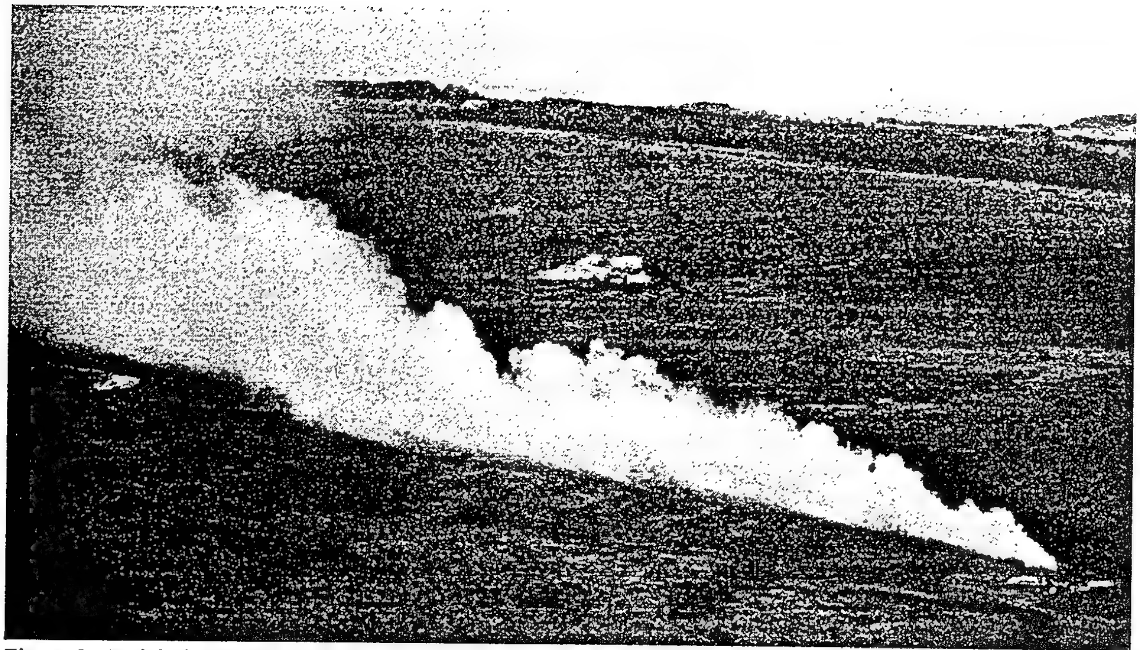

Figure 2. Aerial view of a continuous smoke plume traversing the Porton Down Bowl area.

always measured the smoke concentrations near the ground, the mini-LIDAR system were optionally operated to scan the vertical concentration profiles. The Risø Mini-LIDAR system is operating with an effective range resolutions of 1.5 meter and a time resolution of 1/3 Hz. It was in operation during all of the MADONA puff and plume dispersion experiments. Further description of the lidar systems are presented in Jørgensen et al. Ibid.

In this paper, we will first show some diffusion results obtained during the continuous release experiment MAD 18A, which took place in the Bowl area of the Porton Down terrain on Sep. 18 between 17:42 and 18:42 during approximately 4 m/s wind speed and during near-neutral near neutral conditions. The corresponding mean and turbulence quantities measured by one of the Risø's teams sonic anemometers is presented in an accompanying paper (Mikkelsen and Jørgensen (1995).

Secondly, we will show some diffusion measurements from an instantaneously released puff (MAD 23 H) measured during stable conditions.

CONTINUOUS SMOKE PLUME EXPERIMENT

Figure 2 shows an aerial view of the continuous smoke release which was used in the one-hour long lasting continuous plume experiment MAD 18 A. The mini-LIDAR system was located 550 m down wind of the source and positioned 250 m cross wind from the plume centerline.

The mini-lidar was operated to produce two-dimensional mean concentration isoplethes in a "cross wind-height plane" perpendicular to the mean wind direction. The measured 1-hour mean concentration is shown in Fig. 3. The isoplethes are normalized relative to the maximum concentration at the ground.

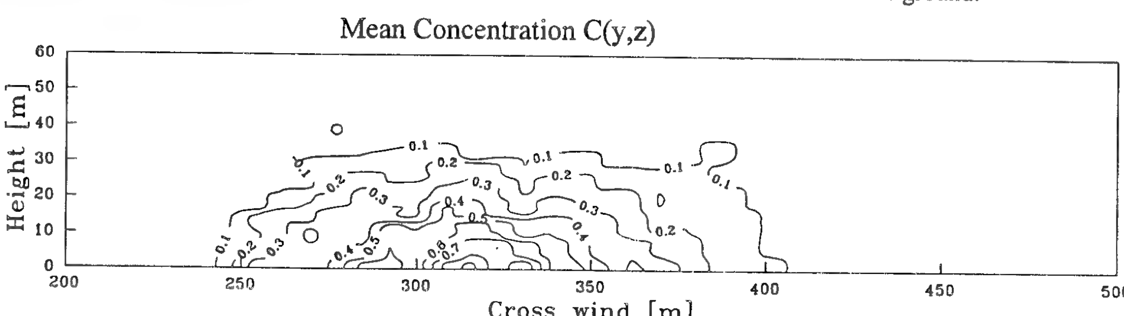

Figure 3. Mean concentration isoplethes from MAD 18 A measured by the Risø mini-lidar system.

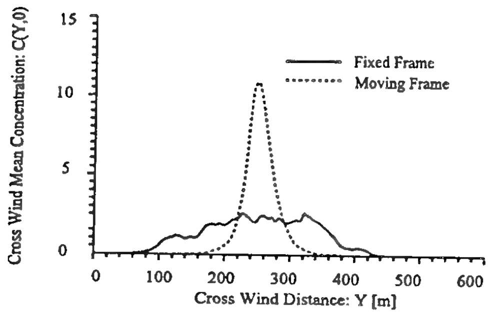

Figure 4. Measured cross wind mean concentrations profiles at ground level during MAD 18 A.

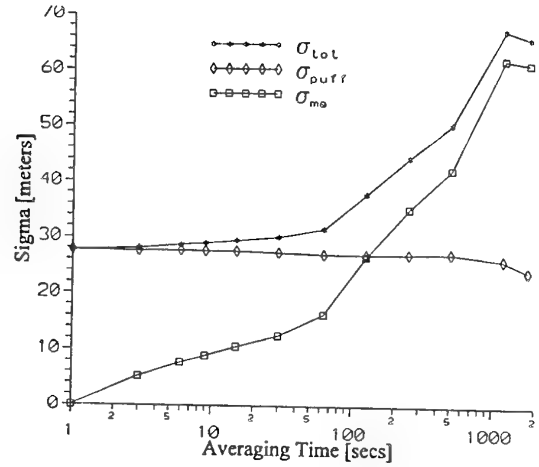

Figure 5. The plume spread in experiment MAD 18 A as function of averaging time.

Legend.

σ_{puff}: *Running-mean averaged instantaneous spread.*

σ_{me}: *Running-mean averaged meander contribution from center of mass movement.*

σ_{tot}: *Total plume spread calculated from:*

$$\sigma^2_{tot} = \sigma^2_{puff} + \sigma^2_{me}$$

The measured mean concentrations at ground level (measured by the lidar beam at approximately 1 meters height above the ground in order to avoid ground clutter) is presented in Fig.4. These measurements are based on the lidar scans taken at the lowest azimuth angle (zero degrees).

Two sets of concentration profiles are presented, a *fixed frame* concentration profile and a *moving frame* concentration profile:

The *fixed frame* curve represents the 1-hour averaged concentration distribution, corresponding to the isoplethes at ground level (z = 0) in Figure 3.This curve includes the spread resulting from plume meander during the measurement period (1-hour). Its corresponding Σ-value is 68 meters.

The *moving frame* mean concentration profile has been obtained by ensemble averaging the instantaneous concentration profiles obtained by the lidar system:

The individual concentration profiles (of which some1200 is obtainable during one hour sampling of the smoke plume with a 1/3 Hz sampling rate) were first superpositioned with respect to their individual center of mass, and them ensemble averaged.

The *moving frame* concentration profile in Figure 4 thereforerepresents the ensemble averaged instantaneous spread, or the plume diffusion without themeander contribribution. The *moving frame* spread (σ_{puff} = 28 meters) is therefore a measure for the relative diffusion (at the 550 m distance) in this experiment.

The MAD 18 A data set also enables a study of the plume spread averaging-time dependency in this experiment, see Figure5. Beginning with the instantaneous value σ_{puff}= 28 meters (corresponding to zero averaging time) the measured plume width increases with averaging time and reaches 68 m (standard deviation) after one hour of continuous sampling. This increase with averaging time is due to the meandering of the smoke plume. The stagnation and slight decrease in σ_{puff} at averaging times longer than 1000 s is due to a decrease in the turbulence level and approaching stable conditions towards the end of the experiment.

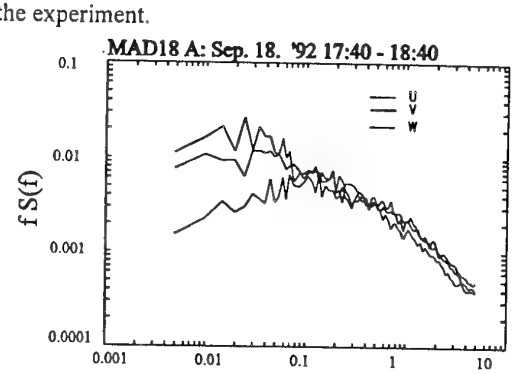

Figure 6. Measured spectra during MAD 18A.

INSTANTANEOUS SMOKE PUFF EXPERIMENT

Also the instantaneous smoke puff experiments were detected by lidar.

Puffs were generated by the Swedish participants by firing of a two component cylindrical charge (containing 100 ml of $SiCl_4$ and 320 ml of NH_4OH) with a burster tube filled with plastic explosive.

Figure 7 shows the firing of Puff No. MAD 23 H (elevated release). The explosion results in an instant smoke puff of initial and often symmetric size $\sigma_{puff}(0)$ of the order of 2-3 meters.

Puffs were sometimes additionally accompanied by a small balloon containing measured amounts of SF_6 and were in addition to the lidar detection systems also measured by a mobile SF_6 flame detector system operated by the Germans.

Puff MAD 23 H was released in the evening on Sep. 23 during low wind speeds (2 m/s at 7 meters height) and strong stable conditions ($z/L \approx 1$) as can be seen from the sonic measurements (Mikkelsen and Jørgensen (1995).

Figure 8 shows the 1/3 Hz lidar-measured cross section concentration profiles at ground level some 100 meters downwind from the release point. First follows the bulk part of the puff, then follows a long (10-min long lasting) tail that sticks to the ground, see also Figure 1. Meandering is here seen to be suppressed.

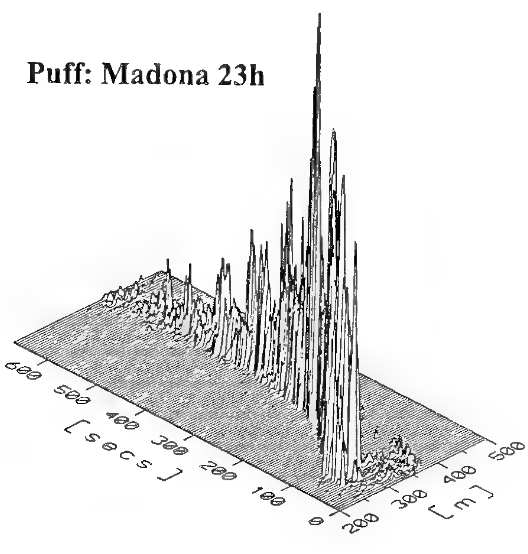

Figure 8. Lidar cross-sections at ground level from the instant smoke puff release MAD 23 H ($z/L \approx 1$).

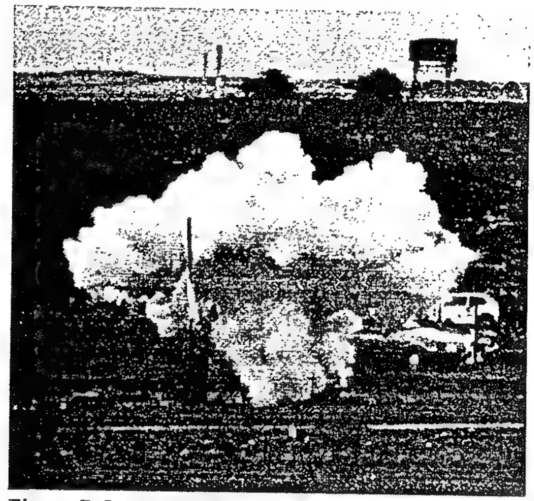

Figure 7. Instantaneous smoke puff detached from the source point (ground level view).

Acknowledgements

Part of this work (contributions by Risø National Laboratory and DLR) has been sponsored by the Commission of the Eropean Union (EU-DGXII Radiation Protection ResearcProgram, under contract No. FI3P- CT92-0044, "RODOS").

Risø's participation in the MADONA trials was made possible by a travel grant by U.S. Army Research Development & Standardization Group-UK, under contract No.DAJA45-92-M-0344.

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Mikkelsen, T. and H.E. Jørgensen (1995) MADONA: On-site real-time turbulemce measurements. Ibid.

MADONA:
ON-SITE REAL-TIME TURBULENCE MEASUREMENTS

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1. INTRODUCTION

Two sonic anemometers/thermometers (Kaijo Denki DAT300), displaced by 100 meters and mounted on 7-meter tall met-towers, were operated by the Danish team during the Porton Down MADONA trials.

On-line data processing and quality assurance of the Danish-teams wind and temperature measurements formed the basis for real-time state and stability characterization of the turbulent surface layer over the field trial terrain. Running continuously during the entire experimental campaign September 14 to 23 1992, the sonic data provided real-time surface layer turbulence statistics of the most important scaling parameters for the in-situ dispersion assessments and modelling, including:

1. Mean Wind speed, Direction, Turbulent Kinetic Energy, Shear Stress, Sensible Heatflux, Monin-Obukhov Stability parameters and Temperature statistics.
2. Time series plots of high-resolution (10 Hz) wind and temperature signals.
3. Time series of short-time averaged (1-min running mean) quantities of wind speed, direction, turbulence level, shear stress and heat flux.
4. Spectral analysis of the three wind (u',v',w') and temperature (T') signals.

This information is now available during the MADONA analysis and model evaluation phase. The mean and turbulence data have in particular proven useful for:

- Insight in fine scale temporal evaluation of the boundary flow and turbulence over the Porton Down terrain during each diffusion test.
- Information about the spatial in-homogeneity of the turbulence over Porton Down.
- Insight in the turbulent scales and their importance for the exchange and diffusion processes.
- Detailed turbulence measurements near the source point for use in the model simulation of the experiments.

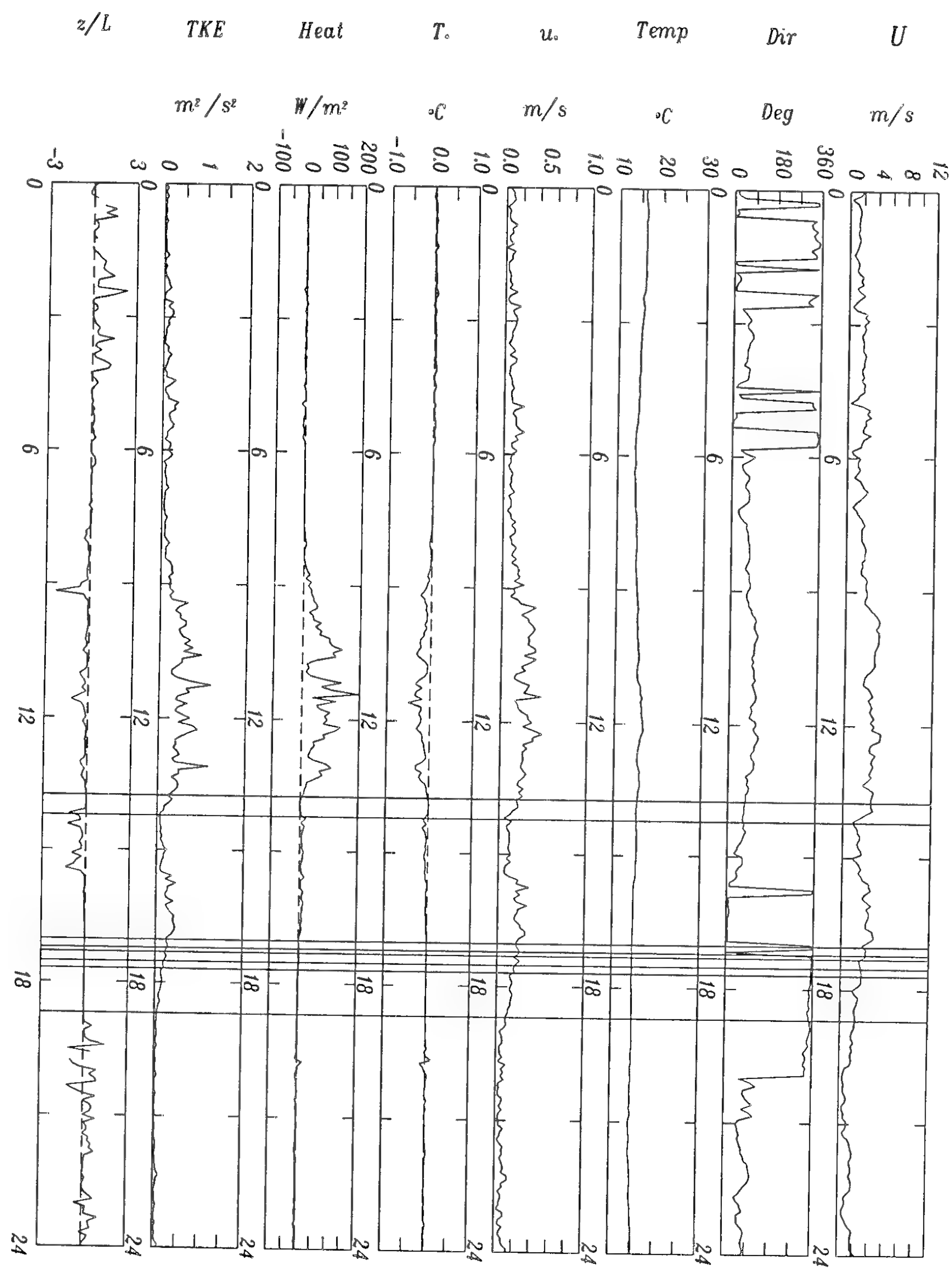
EXAMPLES OF DATA OBTAINED

MAD18: Sep. 18., see next page:
Mean and turbulence measurements obtained from Sonic 1. The vertical lines and bars indicate the start, occurrence, and stop of puff and plume release periods.
MAD23: Sep.23., see last two pages:
Mean and turbulence data obtained on Sep 23 from sonic1 and sonic 2, both located in the Porton Down Bowl area and separated by 160 meters.
Although the terrain is non-homogeneous and therefore varies somehow between the two sonic sites, the obtained (10 min averaged) statistics is remarkable identical at sonic site 1 and sonic site 2.

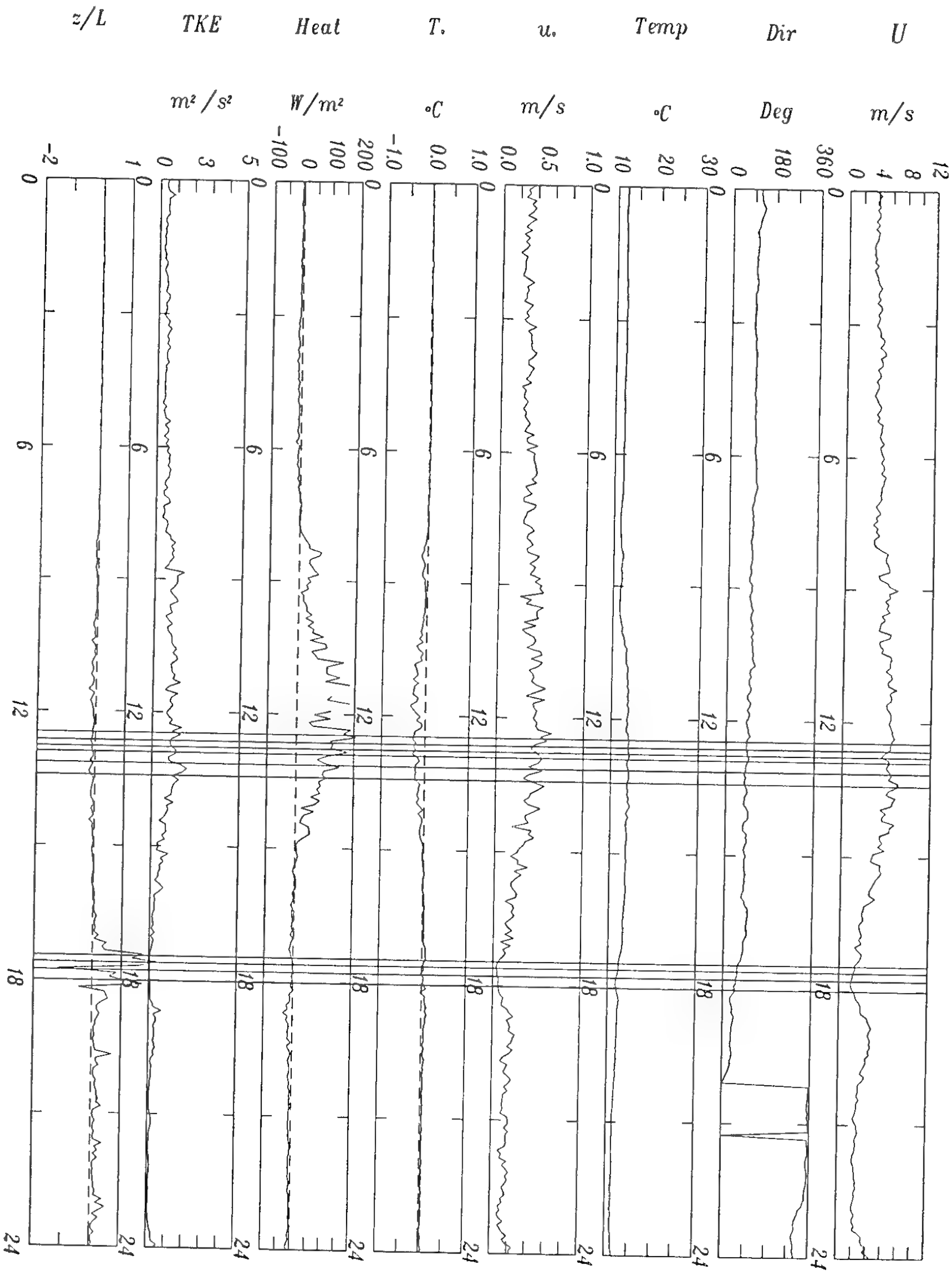
Acknowledgements
Part of this work (contribution by the Risø National Laboratory) has been sponsored by the EU DGXII Radiation Protection Program "RODOS", under contract No. FI3P- CT92-0044).
Risø's participation in the MADONA trials was made possible by a travel grant by U.S. Army Research Development & Standardization Group-UK, under contract No.DAJA45-92-M-0344.

References
Cionco R.M., W. aufm Kampe, C.Biltoft, J.H.Byers, C.G.Collins, T.J.Higgs, A.R.T. Hin, P.-E. Johansson, C.D. Jones, H.E. Jørgensen, J.F. Kimber, T. Mikkelsen, K. Nyren, D.J. Ride, R.Robson, J.M. Santabarbara, J. Streicher, S. Thykier-Nielsen, H. van Raden, H. Weber (1995): An overview of MADONA: A multi-national field study of high-resolution meteorology anddiffusion over complex. Submitted to: *Bulletin of the American meteorological Society.*

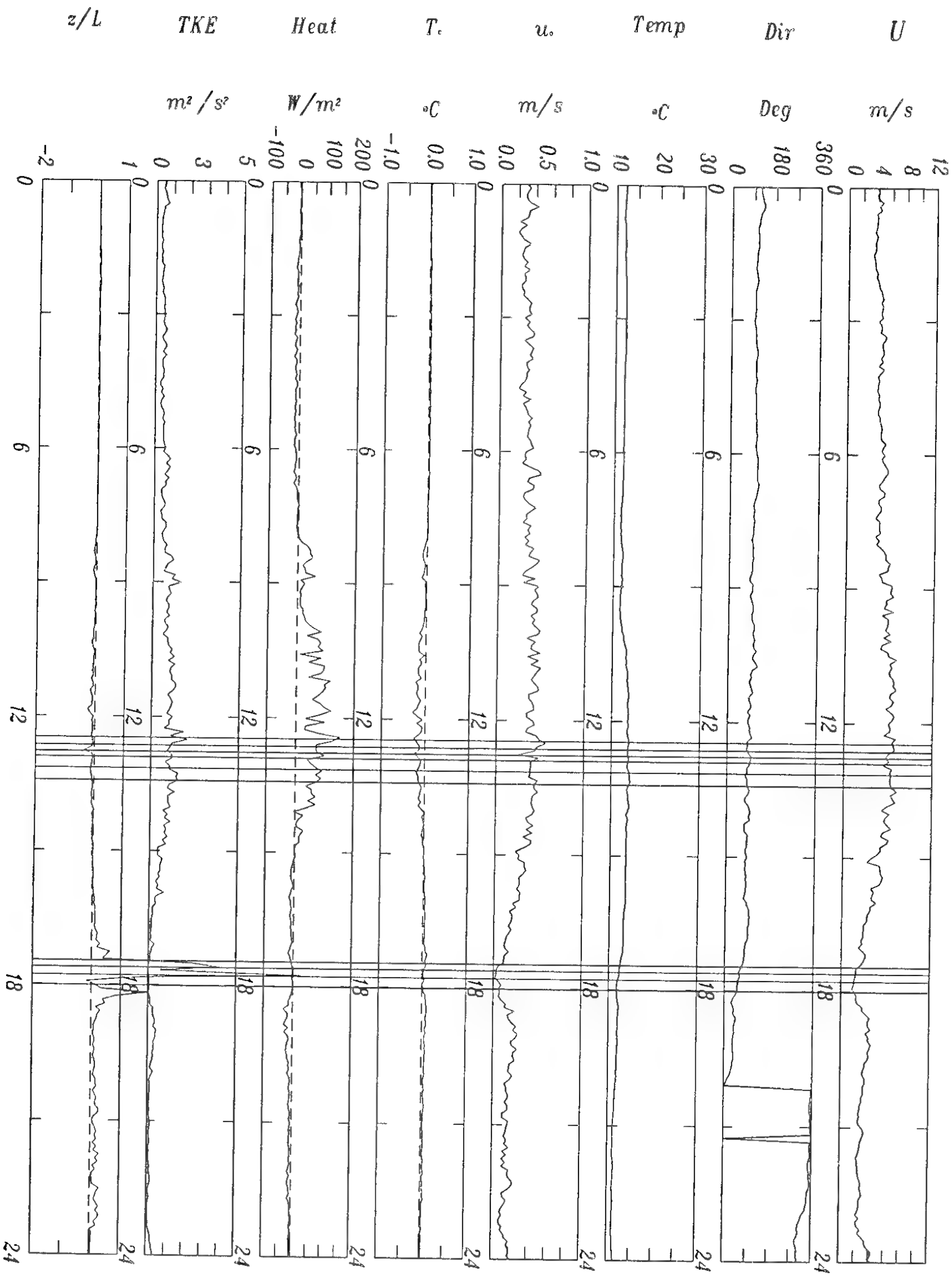
Sonic 1 micromet: 920918 MADONA



Sonic 1 micromet: 920923 MADONA



Sonic 2 micromet: 920923 MADONA



MADONA:
REAL-TIME DIFFUSION MODEL SIMULATIONS

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Risø National Laboratory, DK-4000 Roskilde, Denmark

D. J. Ride and T. Higgs
Assessment and Modelling Division
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Mont Royal, D-5580 Traben-Trarbach, Germany

1. INTRODUCTION

Simulations of the airflow and diffusion over the MADONA topography are now being made with a variety of models. Several simulations were made on-site and in real-time, while others were made after the experiment during the analyses of the observed wind and diffusion pattern. Wind fields and wind-related parameters were simulated with high resolution wind models such as HRW (Cionco, 1985), Ball and Johnson (Ball and Johnson, 1974, and Weber and aufm Kampe, 1992) and LINCOM.

This paper describes the simulation of diffusion of smoke and tracer gas during two of the MADONA experiments using the local-scale real-time dispersion modeling system LINCOM/RIMPUFF.

2. THE LINCOM/RIMPUFF DISPERSION MODEL

2.1 *Flow model LINCOM:*

LINCOM (Troen and de Baas, 1986; Walmsley et al. 1990; Santabàrbara et al. 1993) is an extremely fast diagnostic, non-hydrostatic dynamic flow model based on the solution of linearized versions of the three momentum equations and the continuity equation with a first order spectral turbulent diffusion closure besides.

Its truncated physics (linearization, neutral stratification) restricts it from application to severe non-uniform terrain, but considerable realism in the resulting wind fields can be achieved by use of assimilation techniques to match the models resulting windfield to locally measured tower or forecast winds, as this paper will show.

Stratification effects are in LINCOM accounts for only by matching (based on least square error) the resulting flow field to the available observations. For near-neutral stability conditions, however, the flow model accounts for many terrain features with only modest mathematical and computational effort. LINCOM runs extremely fast in "fitting" mode (100 by 100 grid points are processed in less than 1 second on a 50 MHz 486 DX PC).

A thermodynamic energy balance, based on an estimated or measured temperature field, is presently under development (version: LINCOM-T) (Moreno et.al., 1994) by which stratified flow effects, such as valley and local cold air drainage jets, in principal can be modeled. But even so equipped, this model is not an alternative to a full prognostic, primitive-equation based non-hydro-static flow model that accounts for differential heating (sea-breeze, valley slope and drainage winds etc.).

However, by responding in seconds on a standard PC, LINCOM is an attractive "driver" for fast real-time atmospheric dispersion models such as the puff model RIMPUFF in assessment of emergency response and decision support.

2.2 *Diffusion model RIMPUFF:*

RIMPUFF (Mikkelsen et al., 1984; Thykier-Nielsen et al., 1989; Thykier-Nielsen and Mikkelsen, 1993) is a fast and operational puff diffusion code that is suitable for real-time simulation of puff and plume dispersion during time and space changing meteorology. Also optimized for fast response on a PC this model is provided with a puff splitting feature to deal with plume bifurcation and flow divergence due to channeling, slope flow and inversion effects in non-

uniform terrain.

For real-time applications, RIMPUFF can be driven by wind data from combinations of:

1) A permanent network of meteorological towers,
2) The flow model LINCOM (or similar), and
3) On-line Numerical Weather Forecast data.

The puff or plume diffusion processes are in RIMPUFF controlled by local turbulence levels, either provided directly from on-site measurements, or provided via pre-processor calculations (Mikkelsen and Desiato, 1993). RIMPUFF is further equipped with standard plume rise formulas, inversion and ground level reflections, gamma dose algorithms and wet/dry depletion.

2.3 *Evaluation record:*

Concurrently with the improvements in code, the LINCOM/RIMPUFF modeling system is continuously being evaluated using full scale experimental data. For non-homogeneous terrain applications, recent references include: Thykier-Nielsen et al. (1989); Massmeyer et al. (1990); Thykier-Nielsen et al. (1990a); Kamada et al. (1991); Thykier-Nielsen et al. (1991); Kamada et al. (1992); Thykier-Nielsen et al. (1993a).

3 SIMULATION OF A MADONA EXPERIMENT

The RIMPUFF code (Thykier-Nielsen, 1993) was used in real-time to calculate transport and diffusion of smoke and gas tracer aerosols in the wind fields calculated by LINCOM and assimilated to the on-site continuously operated 15 meteorological stations.

3.1 *LINCOM data assimilation procedure*

Wind fields calculated by LINCOM reflect the terrain-perturbed response to a single upwind "free" or terrain unperturbed input wind. That is, the input wind is the mean speed and direction that would prevail uniformly over the entire model domain in the absence of hills or mountains.

However, the tower observations over the Porton terrain are not "free winds", but are to the contrary influenced by their nearby surrounding topography.

The question therefore arises on how to use terrain-influenced observations for driving a diagnostic Navier-Stoke Eqs. based flow model:

In this particular case, because LINCOM is based on linearized equation, the response from two orthogonal inputs (East and North, say) results in two orthogonal perturbation fields.

The following procedure can consequently be adapted to obtain model windfields that assimilate observations obtained within the terrain best possible:

1. First calculate the terrain-induced perturbations over the entire modeling domain from two unit-amplitude "East" and "North" free winds. This (most time-consuming part) is only done once.

2. Backfit, by using a linear-combination of the perturbations obtained in step 1, the free wind vector that best possible fits (by least-square-error method) the available met-tower observations. (For cases where a single met-tower is used, this can be done exactly).

3. By use of the "best-fitted" free wind vector obtained during step 2 finally calculate the wind field at the actual positions and heights where puffs are being advected.

Further details are listed in Thykier-Nielsen et al.(1993a).

3.2 *Model Simulation*

To date, two experiments have been simulated by LINCOM/RIMPUFF. Those are the experiments of September 17 and 22. In both cases "fitted" LINCOM windfields were used and updated every 5 minutes with the observed wind speed and direction measured at the 15 meteorological stations. The simulations covered a release period of up to 6 hours. The resulting flow and concentration fields are shown on figure 1 to 3.

In a study made by Burman (1994), LINCOM was evaluated using data from one of the Porton trials. Measured wind-speeds and -directions at 9 different locations were compared to those predicted by LINCOM. In general there is a good agreement between measured and predicted values. However some differences are seen where the roughness length differs significantly from the averaged roughness length assumed by LINCOM. Further the study shows the importance of carefully choosing the meteorological stations used in the assimilation procedure (see also: Thykier-Nielsen et.al., 1993a). Only the meteorological stations inside the area where the puffs and plumes were dispersed should be used in the assimilation of observations to the LINCOM calculations.

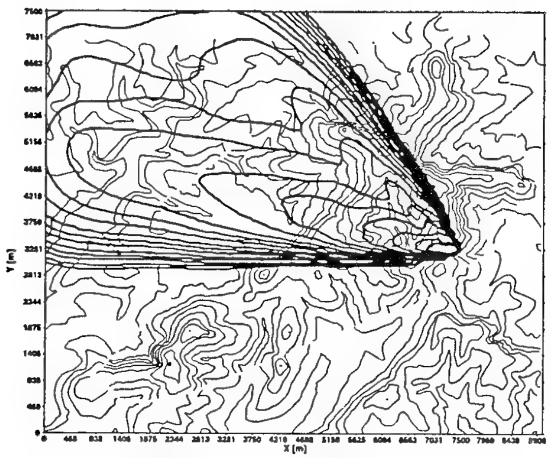

Figure 1. Simulation of an experiment on September 17., 1992: Contours are integrated air concentration calculated by RIMPUFF 5 hours after start of release.

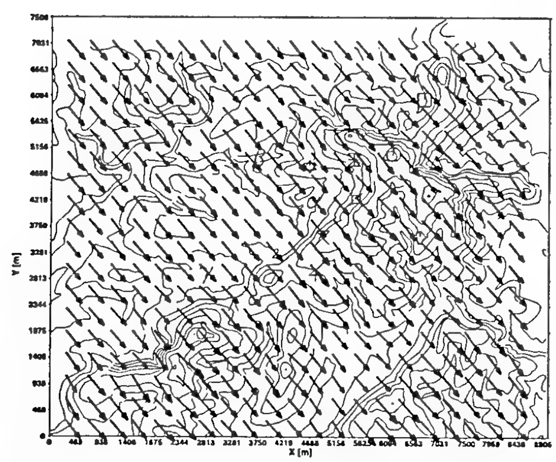

Figure 2. Simulation of the experiment on September 22., 1992: LINCOM windfield fitted to the observations at the 9 meteorological stations inside the model domain. Time: 14:00 hrs, 3 hours after start of release.

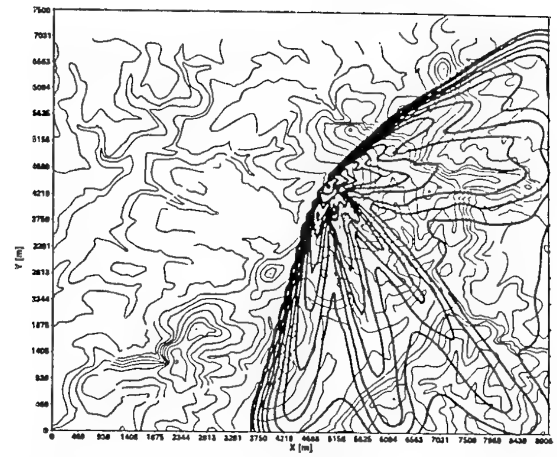

Figure 3. Simulation of the experiment on September 22., 1992: Contours are integrated air concentration at 17:00 hrs, 6 hours after start of release.

4 ACKNOWLEDGEMENTS

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MADONA: CONCENTRATION FLUCTUATION ANALYSIS

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1 INTRODUCTION

The measurements and results presented here were obtained during the MADONA experiment performed at Porton Down, UK, in 1992. A more detailed description of the experiment is given in Cionco et al. (1995). One of the purposes has been to establish a set of data containing concentration fluctuations to evalute existing models for short range dispersion, and to improve the understanding of the natural process of concentration fluctuations.

On the basis of the obtained measurements the concentrations have been analyzed in different frames of reference: the normal fixed frame, the conditional frame, and the moving frame. Often the conditional frame, i.e., the removal of zero concentrations in the measured data, is mistaken as the moving frame (i.e., a frame which follows the instantaneous center of a plume). The present paper shows that there is a profound difference between the result obtained in those three different frames.

Finally the approach of the meandering plume model is discussed and compared with the analyzed concentrations.

2 INSTRUMENTAL SETUP

In the experiments artificially generated smoke was continiously released 0.5 m above the ground. The smoke consisted of particles of SiO_2 and NH_4CL with an average diameter of approximately 0.5 μm. The smoke produced a white visible plume detectable up to several kilometres down wind. The particle concentrations were measured by a Mini backscatter lidar system, Jørgensen and Mikkelsen (1993). Under quasi-stationary conditions and a steady release of smoke the measured backscatter by the mini-lidar can be assumed to equal concentrations with an unkown conversion factor. From other experiments simultaneous measurements of SF_6 tracer in sample backs and smoke particles measured with the lidar have shown that the conversion from backscatter to concentration is very robust. The conversion factor between the measured backscatter and concentrations varied, however, from one experiment to another, Scholten et al. 1994.

The lidar measurements made during the MADONA experiment are relative measures of the concentrations, but for the study of plume dispersion and fluctuations around the mean concentration the measurements have so far not been preeceed with respect to a combined high detailed spatial and temporal resolution, Jørgensen and Mikkelsen (1993).

The cross-wind concentration profiles of the artificial generated plume were measured at 1/3 Hz with a spatial resolution of 1.5 m, corresponding to the effective intstrument respons, but digitized with 0.6 m. During the campaign the Lidar was measureing at different down wind positions ranging from 100-700 m from the source. Figure 1 shows the experimental setup for the lidar measureing the artificial plume.

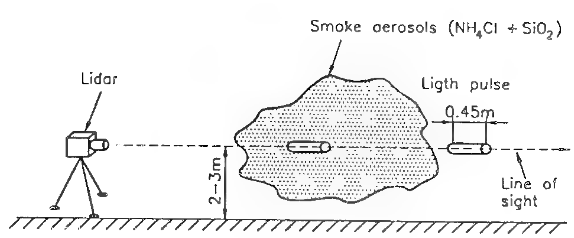

Figure 1: Schematic setup of the lidar system measuring an aerosol cloud.

An example of an instantaneous cross-wind concentration profile measured by the lidar system is

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shown in figure 2. It is seen that the lidar is able to reveal a high amount of the internal structure that occurs in an instantaneous plume.

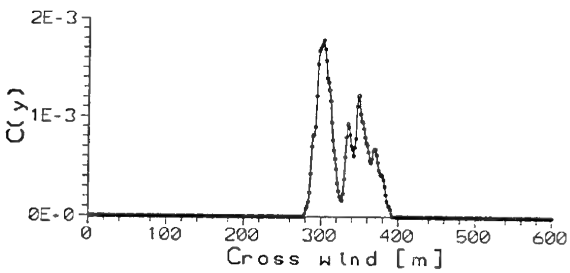

Figure 2: An instanteneous cross-wind concentration profile measured with the Risø's mini-lidar system. The spatial resolution is approximately 1.5 m.

3 CONCENTRATION FLUCTUATIONS IN DIFFERENT FRAMES OF REFERENCE

In the analysis of the concentration fluctuations three different frames of reference have been used, two of which other researchers have used most commonly, Sawford (1986), i.e., the conditional and the fixed frame. The third frame is called the moving frame. The definitions of the three frames are:

- Fixed frame The coordinate system is based on an Eulierian Cartesian grid fixed relatively to the ground.
- Moving frame The coordinate system is based on a moving plume-relative Cartesian grid.
- Conditional frame As the fixed frame, but with all the observed zero's, i.e., values under a specified threshold is removed.

In this paper only one of several experiments is presented; the experiment analyzed mad18a was conducted 18 Sept, 1992 at 17:42-18:42. The meteorological conditions were near neutral conditions with SE winds of 4 to 1 m/s. The lidar was located 550 m down wind of the source and position 250 m perpendicular from the plume centre line, Higgs and Ride (1994). Within the three different defined frames the fluctuation intensity $i(y)$ has been calculated, defined as:

$$i(y) = \frac{\sqrt{\overline{c'^2(y)}}}{\overline{c(y}} \quad (1)$$

The different results of the fluctuation intensity $i(y)$ is shown in figure. 3

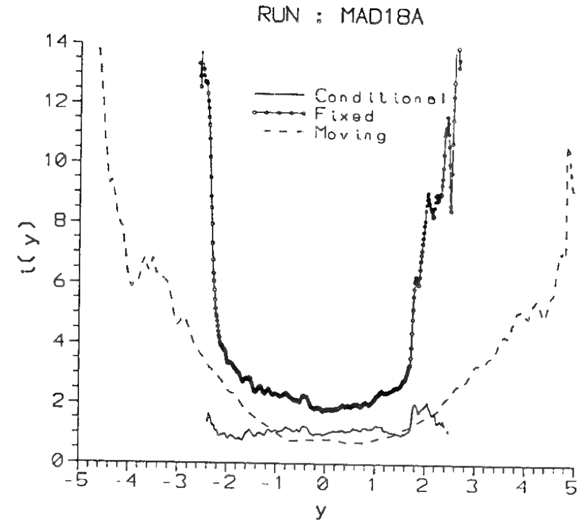

Figure 3: The fluctuation intensity in the three different frames. The x-axis is normalized by the plume size σ

The fluctuation intensity in the fixed frame has the anticipated U-shape also observed by several other researchers . In contrast to the fixed frame the conditional intensity is constant across the plume in good correspondence with wind tunnel measurements. Knowing the intermittency, i.e., the fraction of zero concentration, a simple analytic relationship between the two frames exists, Sawford (1988).

In the moving frame the shape of the intensity is closer to the fixed frame shape, but with a significantly lower level of the intensity in the centre line of the plume. The differences observed within those two frames are caused by the meandering of the plume. The difference between the moving frame and the conditional frame is obvious both in shape and in the level of the intensity. The conditional frame does not account for the relative position of the sensor point to the centre line in the instantaneous plume, but accounts for the variances as long as plume material is present. The moving frame, however, accounts both for the meandering and the relative position of the sensor to centre line in the instantaneous plume.

The cross over point where the intensity in the conditional frame becomes lower than the moving frame is approximately 1.5 plume widths. Here the intermittency in the moving frame drops from 100 % to zero at 1.5 plume widths, see figure. 4, indicating the entrainment of clean air into the instantaneous plume

The shape of the intermittency profile for the present experiment is not unique but is shown as reproducible in similar measurements of plumes from ground releases, Jørgensen (1994).

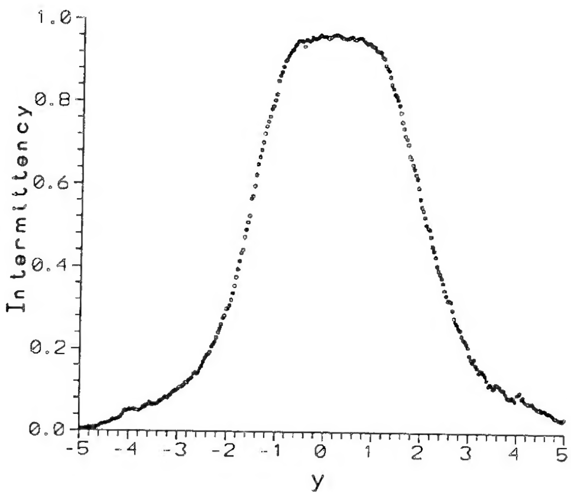

Figure 4: The intermittency of moving frame concentration profile

4 SIMULATION OF C' BY A MEANDERING PLUME

From each of the cross-wind concentration profiles the centre position C_L of the instantaneous plume has been calculated and plotted, see figure 5

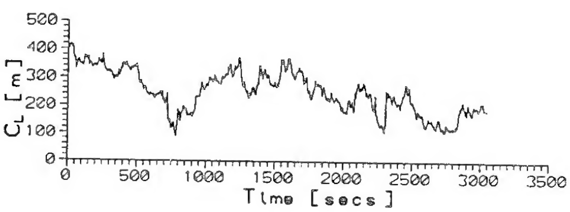

Figure 5: Time series of the C_L positions

The meandering model often assumes that the distribution of the meandering is Gaussian, which for a quasi-stationary period is a reasonable assumption. The mean profile in the moving frame, which corresponds to the ensemble averaged instantaneous plume, has been observed to be near Gaussian as well, see figure 6.

Assuming that there are no internal fluctuations within the instantaneous plume the concentration fluctuation can be simulated by the use of the following equation, Gifford (1959), Sawford (1983):

$$\langle c^2 \rangle = \int \langle c_m(y - C_L) \rangle^2 \, P(C_L) \, \mathrm{d}C_L \qquad (2)$$

where $P(C_L)$ is the distribution of the meandering.

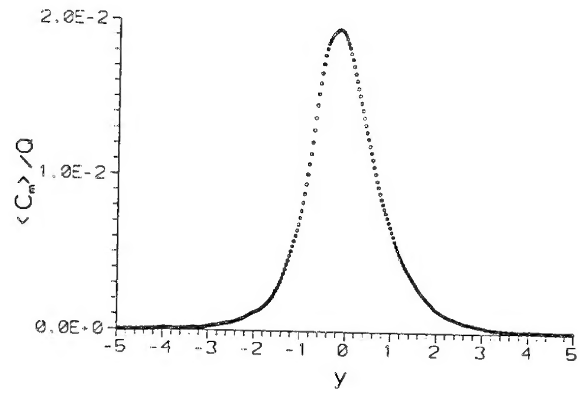

Figure 6: The mean concentration profile $\langle c_m \rangle$ within the moving frame

The concentration fluctuations are then determined by:

$$\langle c'^2 \rangle = \langle \overline{c^2} \rangle - \langle c \rangle^2 \qquad (3)$$

To illustrate the possibilities of the meandering models the measured time series in the centre line is compared to a simulated time series. The simulated time series is created by moving the ensemble averaged instantaneous plume with the actual time series of the centre line positions. Both the simulated and measured time series are shown in figure 7.

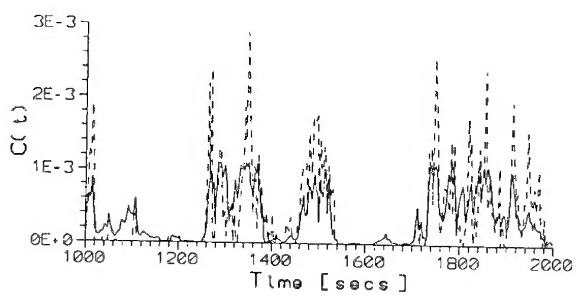

Figure 7: Time series of the concentration in the mean centre line $y = \langle C_L \rangle$ simulated (full line) and observed (stipled).

The results show that in coarse detail the measured time series can be reconstructed, but the high frequency part of the concentrations is missing. Yee et al. (1994) have incorporated this part by applying a model of the pdf for the internal fluctuation in the moving frame. The model assumes that the behavior of the fluctuation intensity in the moving frame is similar to the one in the conditional frame. The intensity is here assumed to be constant across

the ensemble averaged instantaneous plume. The pdf of the fluctuations is taken to be a gamma distribution, which has shown to fit conditional statistics well, Deardoff et al (1988). The model behaves well, although the basic assumptions do not correspond with the physical behavior of the moving frame statistics measured in the MADONA experiments, see figure 8 (In Yee's model the measured moving frame intensity is here used instead of the conditional frame intensity).

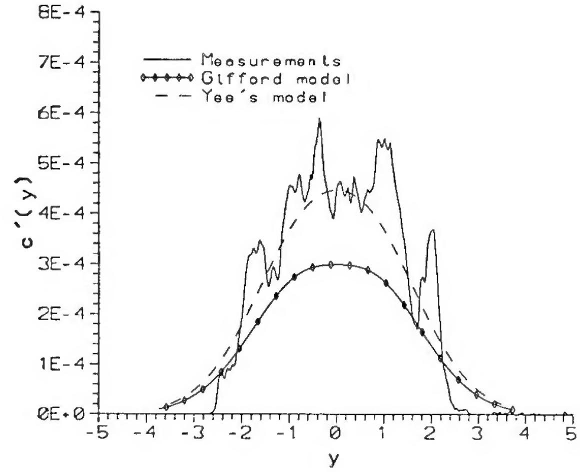

Figure 8: Cross wind profile of the fluctuations c' compared with the meandering model without internal fluctuations, and the model of Yee with internal fluctuations.

However, a more physically based model should contain the correct form of the fluctuation intensity in the moving frame. Finally it still remains to determine the behavior of the centre line intensity in the moving frame as a function of travel time etc.

5 CONCLUSIONS

The experiments contained in the MADONA data base contribute important information on statistics in the moving frame for incorporation into models that are based on meandering of plumes. The analyzed experiment shows a big difference in the statistics in the different frames. This difference is important for understanding the phenomena that create fluctuations in dispersion plumes. For short range dispersion models a large amount of the variance is accounted for by the on-off process caused by the meandering of the plume.

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Bibliographic Data Sheet **Risø-R-852(EN)**

Title and authors(s)

Final Data and Analysis Report on: High-Resolution in Plume Concentration Fluctuations Measurements using Lidar Remote Sensing Technique

Torben Mikkelsen, Hans E. Jørgensen, Søren Thykier-Nielsen, Søren W. Lund and Josep M. Santabarbara

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Abstract (Max. 2000 characters)

The multi-nation, high-resolution field study of Meteorology and Diffusion over Non-uniform Areas (MADONA) was conducted by scientists from the United States, United Kingdom, Germany, Denmark, Sweden, and The Netherlands at Porton Down, Salisbury, Wiltshire, UK during September and October 1992. The host of the field study was the Chemical and Biological Defence Establishment at Porton Down. MADONA was designed and conducted for high resolution meteorological data collection and diffusion experiments using smoke, sulphurhexaflouride (SF_6), and propylene gas during unstable, neutral, and stable atmospheric conditions in an effort to obtain terrain-influenced meteorological fields, dispersion, and concentration fluctuation measurements using specialized sensors and tracer generators. Thirty-one days of meteorological data were collected during the period 7 September through 7 October and 27 diffusion experiments were conducted from 14 to 23 September 1992. Puffs and plumes of smoke and SF_6 were released simultaneously for most of the experiments to gauge the resultant diffusion and concentration behavior. Simultations of airflow and diffusion over the MADONA topography were made with a variety of models. Wind fields and wind-related parameters were simulated with several high resolution wind flow models. A tally of the various data gathering activities indicates that the execution of MADONA was highly successful. Preliminary use of the data sets is showing the high quality and dept of the MADONA data base. This well-documented data base is suitable for the evaluation and validation of short range/near field wind and diffusion models/codes. The data base has been placed on CD-ROM media in a structured way by CBDE, Porton Down.

Descriptors INIS/EDB

AIR POLLUTION MONITORING; COMPUTERIZED SIMULATION; COORDINATED RESEARCH PROGRAMS; DATA BASE MANAGEMENT; DIFFUSION; EXPERIMENTAL DATA; FLOW MODELS; FLUCTUATIONS; M CODES; METEOROLOGY; PLUMES; REMOTE SENSING; TRACER TECHNIQUES; TURBULENCE; WIND

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- *PhD- and Post Doc. education*

Key Figures

Risø has a staff of just over 900, of which more than 300 are scientists and 80 are PhD and Post Doc. students. Risø's 1995 budget totals DKK 476m, of which 45% come from research programmes and commercial contracts, while the remainder is covered by government appropriations.

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